The Journal of ENGINEERING EDUCATION

February 1, 1959 ***Table of Contents*** **Vol. 49, No. 5**

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DO YOU KNOW . . . .

► . . . . That some engineering teachers say, "Why join ASEE, I belong to several professional societies and that is enough?" Yet, teaching long has been called a profession. The engineering teacher thus belongs to two professions and must consider membership in ASEE in the same light, essentially, as membership in any professional society. In the February 20, 1958, issue of *Machine Design*, Editor Colin Carmichael comments on the professional man. Some of his statements, particularly applicable to ASEE, follow. "Society membership does not in itself create a professional man, any more than does education or experience. But it does symbolize an attitude. The non-joiner's attitude may be compounded of procrastination and a 'what's in it for me?' viewpoint. Thereby he might appear to class himself with the followers rather than the leaders. The engineer who is registered and belongs to one or more professional societies has stood up to be counted as a professional man." Each of us should critically review our associates to make certain that all who should be "standing up to be counted" in engineering education are members of ASEE. Give the names to your YET representative or send them to the Secretary of the Society.

► . . . . That 123 names were suggested by the members of the Society as nominees for President? For Vice President for General Divisions and Committees, 135 names were submitted, of which 32 were also suggested for President. 148 names were suggested for Vice President for General and Regional Activities "east of the Mississippi River," 39 of which were common to the list for the other vice presidency; but 12 of the 148 needed to be disqualified because they are located west of the Mississippi River! For treasurer, 59 candidates were suggested. Getting such a wide variety of names is a healthy situation, even though it makes the task of the nominating committee more difficult. The names suggested also are referred to when committees are appointed.

► . . . . That on June 22, 1959 there will be a joint symposium of ASEE and ASTM on "Teaching of Materials"? The 22nd is the Monday following the close of ASEE's annual meeting in Pittsburgh and attendees are urged to continue on to Atlantic City, New Jersey, for the one day symposium. Details of the program will be in a later issue of the JOURNAL. This is another illustration of the way in which ASEE should cooperate with other engineering societies and/or, their education committees for the discussion of common points of interest.

► . . . . That at the recent annual meeting of ECPD the retiring president, Mr. Morris D. Hooven, made a plea for the admission of more societies into ECPD? At the present time three societies have requested membership, but have not been admitted because several present member societies are abstaining from voting. In essence this is a no vote and the admission of the new members is blocked. This question of membership could be a factor in the merging of the activities of ECPD and EJC, and should be eliminated without delay. ASEE has approved membership for each of the societies. Consult with the members of the governing boards of the other societies to which you belong, and which have not taken

similar action, if you wish to aid in overcoming the dilemma.

► . . . . That the Engineers' Council for Professional Development has asked ASEE to make an evaluation study of technical institute education? This action was taken at the request of its Education and Accreditation Committee. The General Council of ASEE accepted the invitation at its meeting in November and authorized President Alexander to appoint an appropriate committee. The committee is to plan the study, seek financing and carry the project through to completion. The study is a logical follow-up of the National Survey of Technical Institute Education recently completed and for which copies of the final report will soon be available from the Office of the Secretary.

► . . . . That ECPD has a "Manual for Engineering Career Advisers" prepared by its Guidance Committee? The twenty-page booklet discusses three stages or levels of guidance, the levels being junior high school, senior high students having an interest in science or engineering, and high school students having a definite interest in engineering as a career. A program with some specific questions for discussion and some "don'ts" is suggested for each level, and a list of 22 references is included. Copies of the manual may be obtained from ECPD at 29 West 39th Street, New York 18, New York for 25¢ per copy, with a 25% discount on orders for 25 or more copies.

► . . . . That an EJC insignia has just been approved by the Board of Directors of EJC? It is a conservative type of symbolism based on the circle concept. The circle is used as a symbol of unity and strength, and the use of a series of concentric circles symbolizes continuous unity of purpose of groups within groups. The words "Engineers Joint Council" are in an outer concentric band and the letters "EJC" are on a central disk. The corporate seal of EJC most probably will be based on the same design.

► . . . . That the Engineering Manpower Commission of Engineers Joint Council has requested a grant from the National Science Foundation to analyze and publish the results of a study of the teaching income and other professional earnings of approximately 5,200 engineering graduates on the faculties of engineering colleges? The study will be similar to the one made by ASEE's Committee on Development of Engineering Faculties two years ago, when slightly over 4,000 faculty members returned questionnaires to EJC. The report of EJC will be on the returns of questionnaires from all engineers, in the same manner as two years ago.

► . . . . That "They Come for the Best of Reasons" is the name of a new publication of the American Council of Education? The booklet is intended to stimulate college teachers to take a close look at their students and to use that appraisal of capabilities and limitations for the development of new purposes and programs in order to improve the quality of higher education. Some random excerpts are: only 55% of college students are in the 18–21 age range—the level of effort is rising steadily—"Joe College" is no more—data which have been received suggest . . . that today's students are different from their predecessors. Even more substantial changes are in the offing—of the more than 1,800 U. S. colleges and universities, 20% enroll fewer than 200 students and 2% more than 10,000—36 of the largest institutions enroll more than one quarter of all college students—older students are increasing in

numbers more rapidly than younger students—in 1957, 22% of all college students were married—the proportion of students earning more than half of their college expenses has probably risen from about 20% in the pre-World War II period to about 40% today—no studies were found which suggest that the earning of part of one's college expenses is related to either student achievement or the length of stay in college—American college students come from the "lower class"—the reduction of racial and religious discrimination in the selection of college students in this country is a recent phenomenon—there is a clear trend toward business administration and the social sciences as major fields of study—of those enrolled who are in the upper 20% of indicated ability, only about half stay to graduation—the mean aptitudes of the freshmen classes vary with the region in which the college is located, the type of college, and its source of support—examination of the scores made by two entering classes on the public school reading test indicated that the mean level of reading was at the *fifth grade*, sixth month; on an arithmetic test standardized on United States public school populations, the mean score was at the level of the *fifth grade*, eighth month—colleges and universities have had, and still have, in their freshmen classes ranges of aptitude and ability that far exceed the common perception of the faculty and administration—the prediction of college academic success is a difficult problem—tentative and largely informal reports . . . suggest that the performance of entering freshmen classes on the commonly administered scholastic aptitude tests has been rising since about 1950—the upward shift in aptitude may be so rapid and so complete as to require a total revision of both curriculum and instruction methods to meet the changed nature of the student body—college faculties have neither fully sensed this radical change nor taken adequate steps to provide challenge and stimulation for these "new" students—college students today are different as a group from their predecessors—students want their colleges to improve—this growing desire in the part of students to interest themselves seriously in the problems of the college before they become alumni is so contrary to established tradition as to arouse suspicion and draw criticism from the colleges themselves.

► . . . . That SSCQT means Selective Service College Qualifications Test? According to the Engineering and Scientific Manpower *Newsletter* of September 5, 1958, the distribution of scores made on the May 1, 1958, test suggests that it is being taken by a larger proportion of men who seek to qualify for 2-S deferment so as to continue graduate study. Almost 42% of the 5,403 taking the test passed with grades of 80 or over. In the test given to a much larger number of examinees in 1951–53 only 11% scored 80 or higher. The Educational Testing Service analyzed the test given in 1951–53 and brought out some interesting facts. Only half the men who took the test in their freshman year passed, whereas 63% of the sophomores and 71% of the juniors passed. Students majoring in engineering distinguish themselves, engineering freshmen making scores averaging 68, and sophomores scores averaging 79; students majoring in education were at the low end of the scale, with an average score of 28 for freshmen and 38 for sophomores. The function of taking the SSCQT is becoming a means of assuring 2-S classification for graduate study.

► . . . . That NSF has started a new series of bulletins called "Scien-

tific Information Activities of Federal Agencies"? No. 1 is dated October 1958. When completed, the series will represent an inventory listing of all significant scientific information sources or activities within the Federal Government. The real value should be as an aid in directing engineers, scientists, and research librarians to the appropriate source of Government-sponsored or supported research information in specific fields. Comments and inquiries should be directed to the National Science Foundation, Science Information Service, Washington, D. C., Attn. URI Program Director. URI stands for Unpublished Research Information.

► . . . . That to facilitate the exchange of information on the activities within the field of automation and computation of the many individual societies, the British Conference on Automation and Computation has started publishing the "B.C.A.C. Bulletin"? Volume I, number 1 is dated September–October 1958. The cost of the subscription is 12s. 0d. per annum, post free. Requests should be sent to "B.C.A.C. Bulletin, c/o The Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, London, S.W. 1."

► . . . . That there apparently are many surveys made to determine the future need for engineers? The Scientific Apparatus Makers Association made a survey of top executives of the nation's five hundred biggest firms and estimate their needs for technical personnel in 1968 as follows: 60% forecast increases of 25% or more, another 13% foresaw an increase of 50 to 100%, and 25% more said that they need twice as many technical employees.

► . . . . That there is an increasing belief that the general public, now and particularly in the future, must be better informed about the work of the engineer and scientist and that efforts to do something about it are beginning to accumulate? The newly instituted "Engineers' Supplement" of the New York *Herald Tribune* is a monthly digest of current developments in the field of science and engineering and is most interesting. In the issue for Sunday, October 26, 1958, the science editor, Mr. Earl Ubell, states, "The theme of this section is novelty in engineering . . . a collection of articles by outstanding practicing and research engineers who are working at the frontiers of engineering development. For the engineer, there are articles which will surprise him with their ingenuity, and they provide real technical information . . . . For the layman, there are also surprises. Some of the things described . . . will seem completely out of this world. To be sure, the reading . . . will provide tough going. But the effort required will yield rich dividends in understanding where engineering is taking our society." The twenty-page section contained articles on radar, robot motorists, atomic energy, rubber vulcanization, the rarer metals, aluminum highway bridges, ship designing, reactor for testing atomic fuel, oil in shale deposits, and production of high purity uranium.

W. Leighton Collins
Secretary

NUCLEAR ENGINEERING AND SCIENCE EDUCATION IN UNITED STATES UNIVERSITIES

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This paper was presented at the recent International Conference on the Peaceful Uses of Atomic Energy at Geneva.

Nuclear phenomena are of interest in so many of the basic and applied sciences that some degree of education in the subject is becoming essential to the training of most scientists and engineers. While this paper deals primarily with university education in nuclear engineering, some reference to other facets of nuclear education is pertinent because of the intimate partnership of many professional disciplines in developing the useful applications of atomic reactions.

The elements of nuclear physics are now well taught in the hundreds of colleges and universities in the United States which offer competent undergraduate programs in science. A list of the graduate schools with strong faculties and facilities for advanced study and research in nuclear physics would include some forty or so universities, well known to all physicists. Graduate work in other scientific areas such as radiochemistry, biology, agriculture, and medicine is on nearly as extensive a scale. In these fields the application of nuclear techniques opens fascinating opportunities for discovery and understanding, while at the same time it creates new problems. These new and powerful tools aid both the search for pure knowledge and the development of practical applications for human use. For this reason there has been a great need for specific training in radioactive and stable isotope technology, a need which was met largely at the national laboratories in the earlier years, but which the universities are increasingly prepared to handle.

The term "nuclear engineering" has developed over the past decade to describe the technology of applying nuclear energy usefully: to the production of heat and power and of neutrons, gamma radiations and isotopes.* While today this technology is based on nuclear fission as the energy source, it is logically concerned also with fusion as a prospective source in the future. Education in nuclear engineering is still very new, and offers many problems and challenges to our universities. The present programs and the plans of the schools disclose a wide diversity of opinion as to how the universities should respond to this challenge. A brief history of educational developments over the past eight years may help to explain the situation.

Development in Education

Our nuclear reactor technology was initially developed by physicists, chemists and engineers of many kinds, working first under the pressures of war-time emergency and subsequently under the continuing restrictions of classified information. These men

* In some universities the longer term "nuclear science and engineering" is preferred to describe much the same technology.

constituted the knowledgeable core. As the government's program to develop power reactors expanded, notably for naval propulsion, the need for greatly expanding this knowledgeable core was clearly evident. Many technical men in government services and on the staffs of industrial contractors who might build reactors had to be trained in the new technology. Some of this training was effected by assigning such men for limited periods to work at the Argonne National Laboratory, which centered its attention on reactor development. In 1950 the Oak Ridge School of Reactor Technology (ORSORT) was established, affording an 11-month educational program on a classified basis. ORSORT has sharply modified its operations as universities have inaugurated adequate nuclear subjects, but its contribution in training some 600 men, during the period when universities were unprepared to offer adequate instruction, was highly effective.

Subsequently the formation of the International School of Nuclear Science and Engineering at the Argonne National Laboratory in 1955 contributed greatly to the training opportunities for foreign nationals.

The desirability of establishing nuclear engineering programs in universities was well recognized by some educational leaders and by our Atomic Energy Commission. Young men with a comprehensive educational foundation and a keen desire to make their careers in nuclear enterprises are the essential cadre for future leaders in realizing the potentialities of the atom. But the obstacles facing the universities were great. How could one have the free flow of information and ideas between teacher and student, imperative to good education, under the existing security regulations? How could the schools recruit or develop competent faculty members in this new area of technology? How could the schools afford the heavy expenditures for new facilities which loomed ahead? Fortunately, the first of these obstacles—restrictions on information—was soon to disappear with the advent of President Eisenhower's Atoms-for-Peace policy and the subsequent disclosures at the United Nations Conference on Peaceful Uses of Atomic Energy in 1955. This Conference demonstrated that much supposedly-secret information was known quite independently by other industrialized nations. The other two evident obstacles—staff and money—have been and still are major problems.

Credit for constructing the first university reactor for training and research and for inaugurating a nuclear engineering program belongs to North Carolina State College of Agriculture and Engineering. Dr. Clifford K. Beck, a leader in nuclear research at Oak Ridge, became head of the Physics Department at North Carolina State in 1950. By 1953 he had built a water-boiler reactor there, aided by a grant of private funds. Many new questions of government-university relations in the nuclear field had to be resolved in this pioneering enterprise. North Carolina State elected to establish an undergraduate program leading to the degree of Bachelor of Nuclear Engineering, but for reasons to be discussed later, other schools have not followed this particular pattern.

The second university research reactor was erected at Pennsylvania State University under the leadership of Dr. William M. Breazeale. Like Dr. Beck, Dr. Breazeale came from Oak Ridge to his academic post. The reactor, which started operation in 1955, is of the swimming-pool type which he helped develop at Oak Ridge. Penn State does not offer a degree program in nuclear engineering but uses its reactor and associated

facilities principally for graduate research.

Two other schools which can be classed as pioneers are the University of Michigan and the Massachusetts Institute of Technology (MIT). Ten years ago Michigan embarked on a campaign among its alumni for funds to support a comprehensive study of nuclear energy in all aspects of its peaceful application, social and legal as well as scientific and engineering. Nuclear engineering education has developed at Michigan with the stimulus afforded by this enterprise. A research reactor of the swimming-pool type started operation last fall, and programs of graduate study towards the Masters and the Doctorate degrees are well established. The story of MIT's efforts will be considered later as a specific example of one university's problems and how they are being met.

Obstacles

Mention has been made earlier of two major obstacles facing a university as it contemplates establishing nuclear engineering education—namely, staff and money. The Atomic Energy Commission has in recent years provided several types of assistance to stimulate educational activity in the universities:

1. It loans fissionable materials, neutron sources and heavy water, and it fabricates fuel elements, prepares fuel solutions, and reprocesses used fuel for university reactors without charge.

2. It makes grants of up to $350,000 per institution for the purchase of laboratory equipment needed in instruction. As of this spring, 68 educational institutions have been granted a total of nearly 7 million dollars.

3. It provides special fellowships to well-qualified students for graduate study in nuclear technology, with emphasis on reactor development. Fellowship holders may enroll at any of 40 universities on the current AEC list if they are accepted by that university. 81 Fellows operated under these grants last year, and a somewhat larger number is anticipated for 1958–59.

4. It assists in providing special training in nuclear technology for engineering educators so that they may incorporate such material in their teaching. The training is given during the summer, both at national laboratories and at certain universities. About 190 educators, from over 100 schools, are enrolled this summer.

Additional support comes from the National Science Foundation, specifically for research, and from other sources available to specific universities, such as grants from states, private foundations, industry and individuals. Nevertheless, many schools hesitate to commit themselves to the prospective investment of their own limited funds in facilities and additional faculty and, even more, to the continuing costs of operating advanced instruction in nuclear engineering. A study of some 75 schools which give some work relevant to nuclear engineering indicates that only perhaps a dozen are today able to offer a reasonably broad and integrated program of graduate school calibre. This number may increase significantly under the stimulus of recent governmental support.

One method for expanding the university's educational operations economically is an arrangement whereby graduate school students get part of their training, especially in doctoral thesis research, at national laboratories such as Brookhaven, Oak Ridge, Ames and Argonne. The practicability of such arrangements on a large scale is naturally dependent on geographical location. The national lab-

oratories can offer facilities and experience in special areas far beyond that of the university. The possibilities for profitable cooperation are excellent, when the laboratory staff is interested in education as well as in the technical problem, but the method should not, of course, be merely a device whereby the university relinquishes its own prime responsibility for the educational development of its students. While most of the student investigations at national laboratories are in science, it seems probable and desirable that engineering thesis research will increase as the educational effort mounts.

Professional organizations of various kinds are playing a significant role in advancing education and student interest in nuclear engineering. In 1955 a nuclear congress organized by the American Institute of Chemical Engineers opened up for free discussion many technical topics which had been known to only a few, and encouraged engineering educators to explore the prospects of incorporating this new technology in their curricula. The American Nuclear Society and the Atomic Industrial Forum have made special efforts to stimulate training, and the American Society for Engineering Education cooperates closely with government agencies and the schools in planning summer courses for faculty, teaching and demonstration grants, and special fellowships.

University Education in Nuclear Engineering

At this point it seems pertinent to discuss the nature and purpose of university education in nuclear engineering. There is considerable confusion and some disagreement today about how the educational task should be handled, but certain concepts are gaining wide acceptance. Thus, it is generally agreed that nuclear engineering is not a basic field for undergraduate education but is an area for specialization in graduate school. Development of the potentialities of the atom calls for many different talents: for men who are trained in such fields as physics, chemistry, metallurgy, chemical engineering, mechanical engineering and electrical engineering, and who then specialize in the application of their professions to the problems of nuclear technology. It is logical, therefore, to admit able students for graduate study whose earlier trainings have been in a variety of scientific and engineering disciplines.

It is unrealistic to conceive of a "nuclear engineer" who is equally competent in all areas: in the calculation of reactor lattices, in the design of specialized heat transfer equipment, in the development of better chemical processes for processing spent fuels, and in the discovery of new materials which will retain desired properties under nuclear bombardment at high temperatures. These are tasks of the physicist, the engineer and the metallurgist. But they are tasks which require an overall comprehension of the special characteristics of nuclear technology.

Graduate specialization in nuclear engineering should aim to cultivate this comprehension. The challenge which it faces is to produce the young men who will become the initiators and developers of new processes, the designers and constructors of economic plants, and, in the ultimate, the industrial statesmen of the nuclear age.

Organization

The specific organization of nuclear engineering in different American universities follows many diverse patterns, although the administration is almost always in a School of Engineering. Perhaps one extreme is the separate Department of Nuclear En-

gineering, illustrated by the University of Michigan and by MIT since July, 1957. Such a scheme requires that the faculty of the Department include individuals with competence in many areas. A quite different administrative policy is ably described in the paper presented for this Conference on "Education for Advanced Nuclear Work" by V. L. Parsegian, Dean of Engineering at Rensselaer Polytechnic Institute. His paper advocates the infusion of relevant nuclear technology into each of the existing departments rather than the creation of a separate department.

Often the development of nuclear engineering is assigned to an existing department, e.g., to Physics at North Carolina State and, initially to Chemical Engineering at MIT. More generally, a faculty committee with members from several departments is assigned the responsibility or acts in an advisory capacity.

This variety of approaches to the administrative problem illustrates both the individual character of different schools and the youthfulness of nuclear engineering. It seems unlikely that any standard pattern will soon become established and widely accepted. Each university has its own ideas and personalities, which greatly influence the local decision about administering nuclear engineering. Perhaps even more decisive will be the effect of newly-evolving concepts about engineering education in general which are fermenting in educational circles.

A Specific Example

A specific example of nuclear engineering education in the United States, drawn from the experience of my own school, MIT, may serve to illustrate many of the problems which have been discussed.

MIT's original step, taken in 1948, was to establish with the AEC and its Oak Ridge contractor a School of Engineering Practice at Oak Ridge, patterned after the School of Chemical Engineering Practice which it had been operating for twenty-eight years. Graduate students in chemical engineering, mechanical engineering, and physics spent four months at Oak Ridge under the supervision of an MIT professor and an instructor, working on new engineering problems in both the production facilities and the research laboratory. This School does not attempt to give comprehensive training in nuclear engineering, but it deals with many facets of nuclear design and operation. Today many nuclear engineering students include it as a part of their program.

Nuclear Engineering was inaugurated as a Graduate School curriculum at MIT in 1951, when Dr. Hanson Benedict came from industry to become Professor of Nuclear Engineering in the Department of Chemical Engineering. With one other faculty member he organized instruction in nuclear reactor theory and nuclear engineering and arranged for special subjects in the Physics Department on nuclear physics and on the biological effects of radiation. In those first years of instruction the difficulties imposed by security restrictions were severe. The instructor could not use data which were essential to the subject, and he was constantly frustrated in preparing lectures and leading classroom discussion by the fear of revealing classified information. These difficulties diminished with the years and had practically disappeared by 1955.

Nuclear engineering was established within the Department of Chemical Engineering only so that it might develop in a sympathetic environment with experienced administration. From the beginning it was planned that a separate Department of Nuclear Engineering would be

created when the new enterprise acquired sufficient stature.

Interest in nuclear technology attracted students from several departments, notably chemical engineering, physics, and mechanical engineering. At first most of these men were studying towards degrees in other fields, but increasing numbers registered in nuclear engineering as the staff and its offerings expanded. Today the staff has increased to nine faculty members and there were ninety-four students last year—twenty-five studying for the doctorate and the others for the master's degree. In addition, many students from other departments take subjects in the curriculum, and a fair number have done their thesis research with the nuclear engineering staff.

The individual backgrounds of the nine faculty members illustrate the diversity of talents and experience which have seemed desirable in recruiting an integrated nuclear engineering staff. Their educational training shows:

1 physical chemist and chemical engineer
2 experimental physicists
1 reactor physicist
1 theoretical physicist
1 biophysicist (part-time)
1 chemical engineer
1 electrical engineer
1 mechanical engineer

Three of these men have had extensive experience in national laboratories. Three others have mature backgrounds in private industry. Two have come from other departments at MIT, and one is Chief Physicist at the Massachusetts General Hospital.

The student body is similarly diverse. Physicists and chemical and mechanical engineers are most numerous, but about ten other fields of undergraduate training are represented. Incidentally, about 20 per cent of the students are foreign nationals and another 25 per cent hold AEC fellowships.

The subjects offered today deal with:

Introduction to Nuclear Technology
Biological Effects of Radiation
Nuclear Reactor Physics
Nuclear Reactor Engineering
Nuclear Chemical Engineering
Nuclear Plant Dynamics
Engineering Practice School at Oak Ridge
Nuclear Reactor Physics Laboratory
Nuclear Reactor Laboratory
Introduction to Thermonuclear Processes
Theory of Neutral Particle Transport

Other relevant subjects such as Nuclear Metallurgy and Advanced Heat Transfer are given by other departments.

MIT feels that its nuclear engineering program has now matured as originally hoped, and it has accordingly established a separate Department of Nuclear Engineering this summer.

The history of planning for a research reactor at MIT illustrates how ideas in this new field change with time and experience. In 1951 it was felt that a reactor at the university would be quite unnecessary. By 1953 the thinking had completely reversed —some kind of reactor on the university grounds was essential to adequate education, but the type and the possibilities of financing it were quite uncertain. In 1955 an additional faculty member, experienced in reactor design and operation at Los Alamos, joined the staff with the initial responsibility to develop and execute reactor design and construction. MIT proposed to finance the reactor from

its own Alumni Fund, assuming that AEC would provide the fuel.

The reactor was originally conceived of basically as a necessity to nuclear engineering education, but when news of the plans spread through the institution great interest developed in its potentialities for research, especially in the science departments. This brought about an upward revision in reactor planning to assure its utility for many research purposes. The final design, for a heterogeneous reactor moderated and cooled by heavy water, far exceeded the original ideas and the first cost estimates. The National Science Foundation contributed $500,000 to defray part of the extra costs which were attributable to the reactor's research potentialities, and the Rockefeller Foundation granted $250,000 towards the expense of including facilities for medical therapy research.

The over-all cost, including site and buildings, totals about three million dollars. This does not include the fuel elements nor the heavy water, which are loaned by the AEC, nor certain equipment for laboratory instruction which was purchased through an AEC grant. Construction was completed this summer, and the reactor is now operating.

It should be recognized that the MIT reactor is far too expensive to be rational if one considered only its values in nuclear engineering education. Rather, it is a powerful and versatile research facility, useful for multiple purposes, many of which cannot now be predicted.

Summary

Summarizing briefly this discussion of university education in nuclear engineering, it appears that:

1. Nuclear engineering is a field of graduate school specialization for students from many different professional trainings who will develop the ability to apply their own professional talents to the advancement of nuclear enterprises.

2. The most critical problem is a competent and inspired faculty, drawn from several professions, and dedicated to meeting the educational challenge.

3. The program becomes expensive, especially if good research facilities are provided at the university, and strong financial support from government seems essential.

4. In the present stage of development, nuclear engineering education is highly experimental. It is a healthy sign that many varied ideas are being prosecuted.

World Relation

In closing, let us look at nuclear engineering education in a quite different context—that of world relations.

Our great universities, in the United States and in other countries, cultivate and radiate knowledge. With knowledge comes understanding. The leading professional schools are especially effective because their reputation attracts students from all parts of the world. These young men become an integral part of the university community and develop feelings of mutual respect and of brotherhood with their fellows. On returning to their own countries, they can be foci for international understanding. They can be catalysts to dispel ignorance—the ignorance which breeds fears—the fears which breed hatreds between peoples.

Mankind entered a new era with the advent of the Atomic Age. We will learn to live peaceably together —or we will perish together.

In this context, education in nuclear engineering has enhanced significance. This new technology belongs to the world. We should foster it in every

way, with faith that the constructive forces released by peaceful development and mutual help will lead to more intelligent and rational relationships between the peoples of the world.

AEC MODIFIES THIRD INVITATION UNDER POWER DEMONSTRATION REACTOR PROGRAM

John A. McCone, Chairman of the Atomic Energy Commission, has announced further modifications of the Commission's third invitation to industry for participation in the Power Demonstration Reactor Program.

Through this program the Commission provides assistance to industry toward the development of nuclear reactors and the advancement of the time when nuclear power will become economically competitive. Commission assistance includes funds for research and development, performance of research and development in Commission facilities, and waiver of normal charges for the use of fissionable material for limited periods of time.

The Commission will also consider requests for making heavy water available on a lease basis for research and development during the period prior to reactor operation and for the initial five-year operating period. In addition, the Commission will consider waiving the use on such heavy water for this five-year period.

In conference with recently enacted legislation, the third invitation is further modified to provide that the Commission, prior to entering into any new agreements under the Power Demonstration Reactor Program, will make public announcements inviting proposals for reactor projects it considers technically desirable for construction. In the preparation of such invitations the Commission intends to give consideration to recommendations made by industry as to specific projects. Previously, under the terms of the third invitation, there was no limitation on the type or size of nuclear power plants which might be proposed, except that they must give promise of making a significant contribution toward achievement of commercial use of nuclear power. Now, however, such proposals must be responsive to the type of project specified in the invitation.

Recent legislation extended from December 31, 1958, to June 30, 1959, the final date for Commission approval of proposals submitted in response to the third invitation.

Proposals for projects under the third invitation have been received by the Commission from the Florida Nuclear Power Group, the Northern States Power Company, the East Central and Florida West Coast Nuclear Groups, the Carolinas Virginia Nuclear Power Associates, Inc. and the Pennsylvania Power & Light Company.

THE PLACE OF NUCLEAR SCIENCE IN ENGINEERING EDUCATION

GEORGE B. UICKER

Professor and Acting Chairman,
Mechanical Engineering Department,
University of Detroit

Presented at a meeting of the ASEE University of Detroit Branch, October 18, 1957

The United States Atomic Energy Commission is making every effort to increase the supply of scientists and engineers working in the field of nuclear energy. Of the various programs the one which concerns faculty training is of interest here. This includes a basic course in nuclear science and technology offered at Brookhaven National Laboratory, an advanced course in nuclear metallurgy at Ames Laboratory, Ames, Iowa, and an advanced course in chemical separation at Hanford. A special training course for faculty was offered at the Argonne National Laboratory on the Argonaut Training Reactor.

These courses are given in cooperation with ASEE and were started in 1955, repeated in 1956 and 1957. The Atomic Energy Commission and the ASEE are concerned with the need for faculty members qualified in nuclear science and engineering in our schools and are attempting to assist as much as possible until the schools can handle the problem without help. In fact, the general feeling is that the schools should offer such courses and not the various atomic energy facilities. This is ideally true but as yet there is no school adequately equipped or capable of doing the job as well as the present sponsors.

For the 1957 Summer Institute at Brookhaven National Laboratory, located at Upton, Long Island, New York, 30 faculty members were selected from schools located in the United States and Puerto Rico. The course was given for eight weeks during July and August and was offered to acquaint the participants with the overall problem of nuclear science and technology and also to provide enough background to permit the participant to teach a course in the area if so desired. One of the main objectives of the course was to help the individual participant form some conclusions with respect to the place of nuclear science in our educational processes. From the experience acquired at that Institute, and from the observations made by various distinguished workers in the nuclear science field, the writer has arrived at several conclusions concerning the place of nuclear science in engineering education.

These points will be discussed based on the premise that the engineer should be educated in a manner which will allow him to enter into the field of the application of nuclear science although he may not be educated in specialized courses in that field of endeavor.

Mathematics

Mathematics for theoretical work in the area of nuclear science should include such items as Fourier Series, La Place Transformations, Bessel Functions, and probability.

Quantum Theory

The Quantum Theory enters into nuclear science and a knowledge of

this area is very valuable to an engineer. He does not have to be a theoretical scientist in this field but it is necessary that he know about it in a reasonable degree. I feel that this could be included in undergraduate courses in a number of places starting with elementary physics and continuing in many present courses such as in Analytical Mechanics.

Relativistic Mechanics

Einstein's theory of the equivalence of mass and energy is based on relativistic mechanics. Nuclear science which deals with sub-atomic particles traveling at velocities which approach the speed of light involves the variation of mass with velocity. Actually there is no new theory here but only an extension of the range of application. Kinetic energy is taught in courses from high school physics on. Working in the low velocity range there is no appreciable change in mass with velocity. Consequently it has been customary to treat mass as constant and evaluate Kinetic Energy as $KE = \frac{1}{2} MV^2$. However as we deal with such problems as space platforms, earth satellites, nuclear physics, or high velocity particles in general, it becomes necessary to consider the concepts of the relativistic mechanics. Since this really involves no new theory but merely a more generalized approach to the problem, it seems quite reasonable to expect that this type of material could be developed adequately in the elementary physics and analytical mechanics courses merely by generalizing the approach, i.e. $KE = \int MV\ dv$ with $m = f(V)$.

There are numerous other items of a similar nature and these could be taught in the generalized sense if the faculty is aware of the need for that approach. Without changing the syllabi of many of our courses or introducing new courses in specialized subjects it should be possible to accomplish an adequate breadth of approach.

The specialized approach of the demonstration type, or the repetitive factual information type of solution is apparently detrimental to the student when he is required to approach a problem on the broad basis rather than the specific. Not only does the approach take very valuable time out of the too little time available but it acts as a deterrent to future broadening when it becomes necessary.

Statistical Measurement and Magnitude of Numbers

In dealing with the measurement involved in nuclear science it is necessary to consider and measure in the order of a billionth of a billionth of an inch or to evaluate in the range of billions of billions of particles. It is not reasonable to deal with this problem microscopically, considering each individual particle or length separately. Practically all of the work will be done in a statistical sense. Actually this is not new to the engineer who has been dealing with problems in the macroscopic sense for a considerable time.

It is quite possible and reasonable to teach the concepts of the statistical viewpoint in many of our theory and laboratory courses without introducing new material. However the teacher will have to be aware continually of the need for this type of thinking and interject it at every possible opportunity.

It would be well at this point to illustrate with a few examples how nuclear science affects engineering in general and to attempt to indicate the fact that except for some very detailed, scientific research investigations, the problems created by nuclear science are not much different from those created by the sciences in the past except for the magnitude of the scale of application and the acceler-

ated manner in which the applications of the science are demanded by the pressures of society. It was in 1945 that the first chain reaction was achieved. In 12 years we are attempting to operate, experimentally, 100,000 KW power reactors. That has taken a lot of engineering.

It is interesting to note that the men who are doing this were not trained as nuclear engineers but were educated as engineers in the conventional sense. It is also interesting to note that the problem is "nuclear" only in the "nuclear reaction" and in a few other specialized places. However to get a 100,000 KW power plant operating and producing electricity involves at least 90 per cent or more of the work being in so called conventional engineering. In fact to apply the nuclear physics to a real power reactor in an economical manner involves an engineering concept in itself.

It is quite well agreed by most engineers and scientists that the design of a nuclear power plant involves mostly conventional engineering problems such as structures, mechanical design, metallurgy, electrical power, fluid mechanics, electronics, economy, safety, personnel relations, etc.

It is true that the problems involved in this work are not the same as those involved in other power plants built in the last 50 years *but they never are.* The design of the 250,000 KW turbine generator sets for the Rouge Station of Detroit Edison involved a high percentage of engineering problems which were different from those faced previously. A similar thing is true in the nuclear power plant. The reactor is new in design and is based on nuclear physics. However once the energy is released in the nuclear process the specialty is over. This energy is converted to heat and to work or electricity by conventional engineering theory.

The rate at which the energy must be converted to work is higher, the working substance is sometimes changed from liquid water to liquid metal, the temperature range possibly is greatly increased, the time elements become much shorter, the hazards are different, the economy is different and the political and sociological pressures become important, but actually these problems are all faced in any engineering problem of a large magnitude.

Let me illustrate this viewpoint and form the basis for some conclusions.

Structures

The structures involved to contain nuclear reactors must have integrity and be capable of protecting the public against accidents which might occur within (mainly to protect the public against the release of radioactive products formed in an accident). This means *seal it.* This is different from conventional power plant building design but is actually just another variable introduced into the problem. A qualified engineer can treat this problem without being a nuclear scientist.

However he must appreciate the reason for the problem and be capable of cooperating with other specialists in the area of radioactivity.

The engineer may have to think in terms of interlocking door systems and explosion pressure effects on the structure, but these problems have been faced by other engineers in other areas of endeavor for many years, for instance in the design of a submarine. The fact that the hazard is radioactivity does not make it much different from a hazard such as water or noxious gases in a submarine. Both are hazardous and both must be protected against. Specific designs may look different but *they always do in engineering* because *if it is not a new problem it is not engineering.*

Mechanical Design

Mechanical design is determined by the design criteria. Obviously the design of a nuclear reactor will be different from the design of a combustion type furnace. However except for the rate of energy release and the reaction time for the process, the nuclear power reactor is essentially of the same nature as an oil or coal burning furnace. Certainly the details of design are different but the principles of heat transfer, fluid mechanics, strength of materials, metallurgy, thermodynamics and any other scientific considerations involved are not different. They are merely extended to encompass the problem as it is. The resulting pumps, fans and other auxiliaries may be considerably different but an engineer does not have to be a nuclear scientist to solve the problem involved.

Electrical Design

It is rather obvious that electrical power problems are not affected seriously by nuclear science. Big electric generators used in nuclear power stations are not different from those now in use. In fact in most cases the turbine generator sets are isolated from the nuclear reactor and become conventional power generators.

Such items as electro-magnetic pumps involve theory which is well known to electrical engineers and it becomes a matter of adaptation of theory to practice. Here again range of application becomes a real problem. An electro-magnetic pump will require electricity at a low voltage and a high amperage. One such pump requires 250,000 amps at 2.5 volts. This certainly is different in scope from the so-called "conventional" but should not seriously upset an engineer if he is *educated* to think in basic principles and concepts rather than in specific values and factual information.

Electronics

The instrumentation used in the nuclear sciences involves rather complicated electronic devices. These instruments such as counters, scalers, computers, controls, temperature indicators, etc., are intricate and wonderful but they are not nuclear in concept. They are applications of conventional electronics and very little nuclear science is required to build them.

Economy and Personnel

A person is limited to receive not more than 300 milli-Roentgens of radioactivity in a week to stay within safe exposure limits. The limit is set by the health physicists. This means that if one were to receive a very high level radioactivity exposure for a short time he could get this dose in a few minutes. For instance, if a breakdown involving maintenance were to occur in a highly radioactive area, a man could work in this area for only a few minutes before receiving the limiting dose. This means that if a breakdown occurred which would require say two man hours to repair, it would be necessary to utilize possibly eight men for 15 minutes each. These men would in this time receive the maximum exposure. They would then be required to remain out of radioactive areas for three weeks or a month. That means that, unless these people can be utilized elsewhere on other work, eight man months would be the cost of that particular two hour maintenance job.

This certainly involves engineering economy and personnel problems. However these are just other problems and are not basically different from those a good engineer faces in other areas of the profession. The

problem looks different but the principles involved in arriving at the solution are not new.

Engineering economy is taught in most of our courses and it seems that the kind of thinking involved in this type of problem can become part of the every day work and it would not be necessary to teach this type of problem in nuclear courses as a specialty.

Significance of Magnitude

Another area which is quite pertinent to this problem is the concept of what is important with respect to size and quantity.

In some areas of work one per cent tolerance is close. In others, and in what has been conventional engineering, one part in one thousand was considered reasonable accuracy. Today we face the need to work to one part in a billion in many cases. Consequently we need to be aware of the refinement of the problem and to be teaching constantly the significance of numbers and the importance of the magnitude.

For instance, graphite for a reactor must be highly refined. Ordinary graphite produced for industry in general is too impure. In other words this concept of what is important with respect to impurity has changed from possibly one per cent to the order of parts per billion in the Nuclear Science.

This is not new in concept. This is merely a refinement of existing knowledge and requirements. Of course the engineering problems involved which make this refinement possible are many and complicated but are not nuclear in nature. To refine metal to a high degree involves some good theoretical engineering but this is to be expected as the accuracy of solution demanded becomes more critical.

It was estimated recently that a difference of one foot per second in spaceship orbital speed would change its elevation by 750,000 feet. This is the type of problem we are facing and it is common in the application of nuclear science by engineers.

Long Range Considerations

About 10 per cent of our engineering work will be concerned with nuclear science in a short time. There is need to educate our engineers in the *broad sense* so that they can continue into the nuclear energy field if they so desire.

Before long the problem of the depletion of our fossil fuels will become critical and it will be essential to utilize our nuclear fuels. It is imperative that we be aware of this and start educating in such a manner that a sufficient number of engineers will be available for the purpose when required. Some pessimistic individuals predict the depletion of our fossil fuels by the year 2000, some are less pessimistic and extend it to 2050, but the end is likely in sight with respect to the availability of fossil fuels.

It is necessary that our *undergraduate engineering education* look to the future and produce graduates capable of continuing in the nuclear field in reasonable numbers. However since all will not be nuclear specialists and also since it is not desirable that all should desert the areas already well established and necessary even in the future, it is reasonable to continue our educational objectives as understood today but to modify the approach to make it more general and less specific and factual.

It is apparent that there must be a reasonable number of faculty members familiar with nuclear science and that the general concepts of nuclear science should pervade the whole of the undergraduate curricula, not as specific courses but as an integrated part of each course to suit. For instance, relativistic mechanics could

be included in our mechanics courses, nuclear energy included in the general energy equation in thermodynamics, nuclear related problems introduced into the design courses, and in all courses the concepts of breadth. The general case and modern physics must replace the specific, factual information type work wherever possible.

Conclusions

1. *There is no need for a nuclear engineering curriculum in undergraduate work.* This conclusion was reached some three years ago at the conference of physicists and engineers, held at Northwestern University. There has been no change in the conclusion since that time; in fact there is more evidence to justify the conclusion.

A digest of college programs in nuclear engineering in 1956 shows relatively little activity in this field. The following table shows the number of schools offering courses and includes the number of courses offered:

Number of Schools Offering Nuclear Courses	Number of Nuclear Courses Offered
22	1
15	2
8	3
9	4
3	5
16	more than 5

Analysis of Courses Offered by Departments Offering the Courses

Department	Number of Courses Offered by the Department
Chemical Engineering	63
Physics	53
Nuclear Engineering	47
Mechanical Engineering	41
General Engineering	30
Metallurgical Engineering	10

Most of the courses listed are graduate courses and it will be noted that two of the usual engineering curricula are listed, Chemical Engineering and Mechanical Engineering. These two departments account for about 45 per cent of the total number of courses.

2. There is need to impart to the undergraduate engineering student basic concepts and some information concerning nuclear science. I believe that it should be possible to accomplish this by broadening the teaching approach, eliminating whatever we can of a repetitive nature from our courses, extending the physics and chemistry courses into the nuclear field, minimizing some of the material which has been considered important in the past, eliminating some completely and then carrying the broad concepts on into all of our engineering courses by using applications of the basic principles wherever possible.

It seems that it would be well to teach an introductory course in nuclear engineering to all engineering students in the pre-senior or senior year.

3. There is need to start the student thinking in terms of the small particle theory *early in the undergraduate curriculum.* Preferably start it in the freshman year and continue to include it as a basic part of our courses. Certainly nuclear science is only one phase of our undergraduate education, but it is with us to stay and must become part of our usual educational process and not be considered as a special feature of science fiction. This area of science must be included in most of our courses but it does not need to carry special emphasis or be treated separately.

4. In educating the student to develop him so that he will be capable of dealing with the more complex, high speed, wide range type of engineering, *it is essential that the educational process demand that he be responsible, have initiative and imagination.* This will challenge the faculty

in a very real sense. It will mean the elimination of most of the factual information type of teaching. It will call for the elimination of repetitive type solutions to problems and will call for a considerable amount of effort on the part of the faculty members to introduce basic concepts of the modern scientific world into the particular courses.

It is recognized that this approach will call for more than usual effort on the part of the individual faculty member in keeping abreast of the rapidly changing modern developments which affect his area of teaching. I believe that we are quite capable of doing it and it is only necessary to point up the need so that we as individuals can see it. Our inherent desire to do an excellent teaching job will supply the drive to permit us to achieve success in our work.

5. To be realistic this school ought to consider teaching some nuclear engineering courses. This can be done rather readily in the graduate school, where it is reasonable to teach more specialized and extended material than is proper in the undergraduate school. At that point the student should have been developed to think basically and should be capable of working with the involved theory of specialized nuclear science, if he so wishes. This would allow the student to progress in the area if he so desires and would provide a source of engineers to work in the specialized phases of nuclear engineering.

Again I refer to conclusion 2 above as very important and call attention to the fact that the concepts of nuclear science are a fundamental part of undergraduate engineering education and should be incorporated in all courses.

A very useful purpose can be served by teaching a single introductory course in Nuclear Engineering in the senior year. It will help to crystallize the undergraduate concepts and serve as a transition course leading to advanced work in the graduate school.

VAN DE GRAAFF ACCELERATOR INSTALLED AT CASE

Ohio's most versatile nuclear studies center is rapidly moving toward completion as engineers install a 3 million volt Van de Graaff accelerator in the new addition to the Physics Building at Case Institute of Technology.

The $185,000 accelerator is an indefinite loan from the Atomic Energy Commission, and will be teamed with Case's 30 million electron volt Betatron for a program of education and research in the study of nuclear physics. Manufactured by High Voltage Engineering Corp. of Burlington, Massachusetts, the accelerator is being installed by the school physicists under the supervision of Thomas Kelly, a representative of the manufacturing firm.

The newly completed addition to the physics building provides the school with approximately 75 per cent more laboratory and classroom space in the physics department, much of which will be devoted to nuclear science. Dr. Erwin F. Shrader is director of Case's nuclear activities.

NUCLEAR REACTOR ENGINEERING AND THE ENGINEERING TEACHER

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A discussion of Reactor Engineering directed towards engineers in general.

Although a stage has now been reached at which the engineering teacher finds it practically impossible to keep pace with the new technologies that develop outside of his field of specialization, it seems desirable that he should keep at least imaginative pace with these developments, and perhaps thereby discover new relevance for the work under his charge. The most dramatic technological development of the past ten years has been that of nuclear engineering, and the specialized study of this field has made new claims on universities and colleges the world over. Many engineering teachers are not directly affected by this and have no compelling need to attend an ASEE summer school on the subject. Nevertheless, it is worth pointing out that regardless of the special characteristics and requirements of a particular technology, and nuclear engineering has a multitude of these, there is a certain organic relationship running through it all, an organic unity of engineering thought and practice. This is the justification for this paper. Its subject is nuclear engineering and it is directed towards engineering teachers in general rather than to teachers of nuclear engineering in particular.

Most engineers are now conversant with the essential principle of the nuclear reactor. Certain types (or isotopes) of the heavy metals uranium and plutonium undergo a species of self destruction (fission) under certain conditions whereby a portion of their mass is converted into energy. The nuclear reactor is simply a means of controlling this phenomenon such that the energy is produced at a rate that makes it possible to apply it to the production of power or heat. Around this development have arisen a great many subsidiary developments involving new processes and technologies, but still the central problem is the design of the reactor itself. Energy is liberated in the reactor as heat and this has to be "transported" from the reactor and converted into work. It is as easy as that.

For the purposes of this paper, it will be most useful perhaps to discuss the design of a certain type of nuclear reactor and dwell here and there on certain aspects that seem of wide interest.

Reactor Design

The first step in planning the design of a nuclear reactor is to decide upon its purpose. Is it to produce power? to produce plutonium from natural uranium? to test materials under irradiation? or to produce radioactive isotopes? All of these purposes impose their own peculiar requirements, some of which can be combined in the one reactor and some of which cannot. The purpose decided, the objective is now to design a reactor which will accomplish this purpose as economically as the limiting conditions will permit; the limiting conditions will be imposed by the location of the reactor, the cost and

availability of suitable materials, technological experience and the safety characteristics of the system. So far, the problems are not unique, although they may be unique in detail. Various combinations of fuel, moderator and coolant will be considered from the nuclear and engineering points of view and the feasibility of selected combinations compared. Guidance is required at this stage from the metallurgist and chemist regarding reasonable expectations of the materials favored. Extensive experimentation on these materials is then inevitably required.

Structural materials in the reactor core must be able to retain their desirable properties at high temperature in the face of chemical attack at these temperatures, irradiation damage, and sometimes thermal shock. It is desirable, too, to economize in neutrons and this puts a premium on materials that are poor neutron absorbers.

In addition to these general problems, each reactor type presents special problems of its own. The difficulties increase as detailed design develops. The great majority of the design engineers and engineering draftsmen employed in the nuclear engineering industry have no call to make the overall assessment of a reactor system, nor are they faced with the nuclear calculations involved in determining the amount of uranium or its enrichment or its required spacing in the moderator lattice to achieve criticality. These calculations are properly the province of the nuclear physicist; the engineer's function is to provide the means of meeting the demands of the physicist. Nevertheless, the engineer would find some knowledge of the need for these demands beneficial.

In one common type of reactor, the fissile material or fuel—mainly uranium in the natural or enriched state—is wrought in the form of rods or plates. The rods or plates are enclosed in sheaths of metal—"cladding"—which serve to contain the highly radioactive fission products and to protect the uranium from chemical reaction with the cooling liquid or gas. The individual fuel unit is called a "fuel element." The fuel elements are arranged end to end in channels that are carefully spaced in a mass of moderating material (graphite or heavy water). The arrangement of the channels in the moderator is called the "lattice." The pitch of the lattice is determined by the nuclear physicist from nuclear considerations.

If the reactor is to be designed for the production of power, it is thermodynamically important to release the heat energy at the highest possible temperature. At the present stage of development, the temperature of heat release is limited to the maximum permissible temperature of the fuel element or of the fuel element cladding. For a given maximum cladding temperature and a given rate of coolant flow the rate of heat release increases the lower the temperature of the coolant. Unfortunately, lowering the mean temperature of the coolant results in lowering the temperature at which it leaves the reactor to enter the heat exchanger and hence lowering the thermal efficiency. It follows, by the same reasoning, that raising the mean coolant temperature closer to the cladding temperature increases the thermal efficiency but decreases the rate of heat release of the fuel element. In this case, the decrease in the rate of heat release can be counteracted to some extent by increasing the surface area of the fuel element, say, by finning. The power output of a nuclear power station, then, is proportional to the coolant temperature and the rate of heat release; but since the one diminishes as the other increases, optimum values for each exist in any given case.

Economic Factors

The economics of atomic power plants differ in many important particulars from those of fossil-fuel plants. The most notable difference is that, with an atomic power plant, the capital cost accounts for the greatest fraction of the total generation cost, whereas in a fossil-fueled plant, the fuel costs account for the greatest fraction. It follows that the effect of thermal efficiency on the total cost of generation is less in the case of the atomic power plant than in the fossil-fueled plant. For this reason atomic power plants, to be competitive, must operate with a lower cost per kw. hr. or, in other words, with as large a power output as possible for a given capital investment and operating cost. To achieve this, some sacrifice in the overall atomic plant thermal efficiency may be acceptable and natural uranium preferred to the more expensive enriched uranium.

Natural uranium is composed of 0.712 per cent U235 and the remainder mainly U238. Only U235 is fissionable by neutrons of "thermal" energy. A certain minimum mass of U235—the critical mass—is necessary to produce a chain reaction; hence very much more natural uranium is required to attain the requisite mass of U235 than would be the case if the concentration of U235 in the natural uranium were increased. Natural uranium with its U235 content increased is called "enriched" uranium. Unforunately the "enrichment" process is very involved and costly.

For a lower capital cost, then, it seems desirable to use only natural uranium and to strive for a high rate of "burn-up" of its content of U235. Of course, in the U.S.A., where there is a plentiful supply of enriched uranium, other considerations may prevail and certainly where a small reactor is required, enriched fuel is essential regardless of economy. Another economic factor to note is that the capital and operating costs of an atomic power plant increase more slowly than does the total power of the plant. Hence, the larger the power output, the lower the cost of each kw. hr. produced.

Fuel Element Problem

A high rate of "burn-up," then, is desirable, although from an engineering point of view this raises heat transfer problems with the fuel elements. Uranium is a comparatively poor conductor of heat; hence thin fuel elements are desirable to avoid melting the uranium. For the same reason, the fuel element cladding should have good thermal conductivity. However, severe temperature gradients set up large thermal stresses, and distortion may result which in time may cause variations in cooling and further distortion. It is known, too, that uranium swells considerably under irradiation and "grows" under thermal cycling. The question then arises: must the cladding be strong enough to restrain these effects and contain the build up of pressure of the fission product gases released? Superimposed on these considerations is the concern for the nuclear and mechanical properties of the materials at the temperatures and radiation levels involved. Clearly, the fuel element is a fundamental limiting factor in the design of a reactor of this type. Attention, however, is now being directed to ceramic uranium compounds which can tolerate very high temperatures without ill effects and considerable progress is reported in the development of aluminum and magnesium alloys for cladding.

Choice of Coolant

Turning now to the conversion of the energy liberated in the reactor core to useful work, several possibil-

ities can be reviewed. Perhaps water could be used and converted directly into steam, thence delivered to steam turbo-generators. This would involve the carry-over of radioactivity to the turbines and several thorny corrosion problems. The physicist would be troubled, too, by the problem of reactor stability in view of the differing absorption properties of water and steam. The alternative is to use an intermediate heat exchanger in which steam is generated by the heat from the reactor coolant.

The question then becomes one of choice of coolant—gas or liquid? If a gas, the order of preference on nuclear and heat transfer grounds would be helium, hydrogen, carbon dioxide, nitrogen. If a liquid, the choice would be between water, heavy water, organic liquids (e.g. diphenyl) and liquid metals (e.g. sodium, bismuth, lithium).

The principal advantage of gaseous coolants lies in their safety and general radiation and thermal stability. Their main disadvantage lies in the relatively high pumping power required for a given heat transfer rate. If a great amount of heat is to be transferred from a small space, liquid coolants are to be preferred. The use of water is limited by various nuclear and chemical factors and primarily by its high vapor pressure. Liquid metals have, in general, a lower heat capacity than water and hence demand a higher flow rate to remove the same amount of heat, but they have a much higher thermal conductivity than water and a much lower vapor pressure.

The coolant must be compatible with the materials and nuclear requirements of the system, and economically suitable. Every choice is, of necessity, a compromise. Nature, as usual, takes with one hand while giving with the other. As far as reactor technology is concerned, liquid metals offer most difficulties on grounds of chemistry, containment and, consequently, safety; but experience and knowledge are fast being accumulated. The nature of the coolant and its properties—temperature, pressure and heat capacity—have a considerable influence on the choice of steam cycle and this, in turn, on the design of the heat exchanger.

Detail Design

The moderator, fuel element and coolant chosen, and the system parameters and layout decided, the engineer will now turn to the detailed design of the system components: the pressure vessel or pressure tubes; the support of the core and its contents; the control and safety rod mechanism; the instrumentation; the automatic, operational, and safety control of the reactor; burst slug detection apparatus; fuel element loading and removal machines; shielding design. All of these involve complicated mechanical engineering problems.

It is evident that reactor components will be subjected to severe temperature gradients and stressing at high temperatures over considerable periods of time. In addition, radiation and corrosion complicate the conditions severely. The materials involved are often comparative newcomers to structural applications of this kind and our knowledge of them is still strikingly incomplete. Materials such as beryllium, zirconium, magnesium, aluminum and graphite, and new alloys frequently appear to meet new demands.

It seems almost a commonplace to say that for all of this, the engineer will best be prepared by a good fundamental background. Indeed, this is the most useful background in the preparation of any engineer regardless of his ultimate speciality, but it is especially true of reactor engineering. Here, indeed, is a dramatic synthesizing of the basic engineering cur-

riculum with the addition of an understanding, perhaps no more than superficial, of nuclear physics, metallurgy, corrosion chemistry and chemical engineering processes. The teacher will note, too, that new importance is given the field of temperature stresses and creep phenomena and design procedures where these are involved. For instance, an important problem in certain reactor designs is the bending or bowing of fuel elements. In the British Calder Hall reactor, for instance, six fuel elements are arranged vertically in series in each channel. The fuel elements are solid rods of natural uranium 40 inches long and 1.15 inches in diameter enclosed in a finned cladding of magnesium alloy. Independent support of each element was very difficult and otherwise the complete load, about 170 pounds, was taken by the lowest element. By how much can these elements be expected to bow during their term in the reactor? Fortunately in this case the lowest element is the coolest element in the channel (the coolant flowing upwards). Is the stress, here, taken by the cladding or by the uranium rod? What is the effect of an initial eccentricity of a fuel element? Such questions must be answered by the engineer.

A rather different case of fuel element bowing was encountered in the American E.B.R.I. which was melted down in a reactivity excursion a year or so ago. It has been mentioned in the technical press that the exceptional kinetic behavior of that reactor was thought to be due to bowing of the fuel elements. The fuel elements in the core of this reactor were slender rods. They were bunched together vertically in a hexagonal container and held top and bottom by restraining plates. The elements did not support any significant load, so what would cause them to bow? One possibility is that since the temperatures in the core decrease radially from the centre outwards, a temperature gradient would be imposed across each fuel element. This temperature gradient could cause differential expansion of the element such that it would bend towards the centre of the core. All elements bending towards the centre of the core would introduce more reactivity which would in turn increase the temperature gradient across the elements and produce further bowing and so on. Is the bowing controlled by the cladding or by the uranium and by how much? As the elements bowed towards the centre, the passage of the coolant (liquid sodium in this case) flowing between the elements would be restricted at certain points and so, perhaps, tend to contribute to further bowing of the fuel elements.

One could imagine the control mechanism coming into action to correct for this increase in reactivity and perhaps causing flexing of the fuel elements. If the fuel elements actually came into contact one could expect severe overheating at the points of contact and possible melting of the fuel element cladding (in this case, stainless steel) at these points. This is not an attempt to explain the kinetic troubles encountered in the operating of E.B.R.I., they were much more complicated, but it serves as an illustration of the kind of unexpected mechanical engineering problem that can arise in reactor engineering.

Special Heat Transfer Considerations

Mention has been made of the overall heat transfer problem; but a more detailed analysis involving, say, the plotting of temperature contours in the region of the fuel elements or in the moderator may be considered desirable in certain cases. Here a knowledge of relaxation techniques is very helpful and very often a simple

electrical analogue can save hours of a type of calculation that does not usually appeal to the engineer. In this connection, graphical methods of plotting heat flux and conduction transients are very valuable.

It is, perhaps, relevant at this point to mention a special form of heating peculiar to nuclear engineering: materials exposed to radiation absorb a certain proportion of the radiation incident upon them and thus accumulate a significant amount of energy which is evidenced by a rise in temperature. This phenomenon is given the name of "Gamma heating" or "Self-heating," and is produced mainly by gamma radiation either from the reactor pile or from the capture of neutrons by the material. Several procedures have been suggested for the estimation of this type of heating, and many simplifications can be made for calculations made in any particular reactor. In this case some knowledge of reactor physics is involved. It is worth commenting here that this and certain other unique problems arise in an especially acute form in the design of "in-reactor" materials testing loops.

Design for Maintenance

In the broad overall design of the reactor plant, it is important that moving parts and components likely to require maintenance or replacement be located outside of the reactor shielding and hence outside of the range of radioactivity. Where this is not possible or where inspection of certain components may be thought desirable, it is well to design for inspection and maintenance within the active zone with some thought to the special procedures that may be developed. This, in time, brings us to the important field of reactor operations, as yet in its infancy.

Conclusion

Detailed discussion of many of the topics raised in the foregoing may be found in the literature. It should be remembered that the objective of this paper is to reveal to the engineering teacher in general some of the special demands of nuclear engineering and the essential unity of engineering method and practice extending into the nuclear field. No more than a foundation can be given the student at college level; that which the student builds upon it will be completed only by experience and the experience to learn from experience. The better his foundation, the more he can build upon it. It is helpful to the teacher to have some idea of just how much may be required of it.

NUCLEAR RESEARCH AND EDUCATION AT CATHOLIC UNIVERSITY

The beginning of the academic year 1958–59 at Catholic University saw the institution of courses in nuclear energy technology, use of the atomic reactor presented to the University by the Atomic Energy Commission, and the opening of the recently constructed Keane Physics Research Center.

RESEARCH REACTORS—TYPES AND FLUX LEVELS

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Presented at the ASEE Annual Meeting, Berkeley, June, 1958. Recommended by the Nuclear Committee.

It is the intent of this paper to describe briefly the various types of research reactors currently in use in the United States, to delineate the power levels and fluxes at which they can be operated, to indicate the uses to which such reactors may be put, and to point out the strengths—and by inference—some of the weaknesses inherent in each of these various types. The viewpoint taken here will be that which might be taken by a university nuclear engineering group which is seeking to determine what type of reactor best fits the requirements of the university. The reactor type and the experimental facilities provided both in the reactor and in the adjoining area can be selected so as to fulfill the aims not only of the nuclear engineering program but programs in other fields of interest within and outside of the university community. The university must select a reactor type and a particular reactor design which can be obtained within the budget available, which is suitable for the site selected or available, and which will fulfill the particular needs of the university.

Before the university faculty embark upon such a program they should first insure that there is sufficient interest to warrant a reactor of any type. They should be certain that there is at least a small nucleus of people who are willing to devote two, and probably four years to the construction of the reactor. They must determine whether they have, or can hire, personnel who are competent to design and even to construct their own reactor or whether they will purchase the reactor from a commercial group. They must be sure that they have sufficient funds to operate the reactor once it has been constructed. Finally, if all of these problems have been solved they should, by all means, visit existing installations at other universities and at the government laboratories so that they may be sure that they understand all of the problems and are able to make their final selection of type of reactor, flux and power levels, method of design, and method of construction. This thorough review of the entire situation should be made before commitments of any sort have been agreed upon.

All of the reactor types discussed in this paper exist in commercial versions which can be purchased. It is also true that at least one of each of these types of reactors has been designed and in almost all cases built by a small group in a university or in a government laboratory. It is therefore feasible to adopt any one of the methods mentioned above as a means of designing and fabricating a reactor.

The general characteristics of each of the types of research reactors available today will first be discussed. Then a comparison will be made between the various types on the basis of power level and central flux. Finally, the strong points of each type will be mentioned and their relative usefulness in teaching and research will be discussed.

Review of Reactor Types

Water Boiler

The term "water boiler" is normally applied to unpressurized homogeneous research reactors. The reactor is normally a homogeneous mixture of a salt of uranium, such as uranyl nitrate dissolved in a dilute nitric acid solution or uranyl sulfate dissolved in a dilute sulfuric acid solution. Both of these types have been operated successfully. The term "water boiler" arises from the fact that any sudden increase in power will result in the formation of steam bubbles and these bubbles will in turn rapidly shut down the reactor, thus providing an important safety feature.

The solution is normally contained in a stainless steel sphere approximately one foot in diameter. If the power of the reactor is to be higher than a few watts, a stainless steel cooling coil will be provided inside of the sphere. Due to the high levels of ionizing radiation which are present in the core, considerable amounts of hydrogen and oxygen are dissociated during operation. These gases are normally swept from the core by means of a circulating cover gas and are recombined in a catalytic recombiner.

Beginning with the construction of the "Supo" reactor at Los Alamos it has been common practice to have a diameteric tube of about one inch diameter (for experimental use) passing entirely through the reactor sphere. This hole is called a "glory hole." Control rods for this type of reactor are normally inserted in reentrant thimbles in the top of the reactor. The entire reactor core is located in the center of a large graphite zone which provides an adequate reflector and normally has a number of beam tubes imbedded within it. There is usually at least one thermal column provided in this type of reactor. The region outside of the graphite zone consists of biological shielding. It is possible to utilize the recombiner as a separate gamma research facility.

Homogeneous reactors of the water boiler type listed in the order of their date of criticality exist at: Los Alamos Scientific Laboratory, Los Alamos, New Mexico; Atomics International, Santa Susanna, California; Livermore National Laboratory, Livermore, California; North Carolina State College, Raleigh, North Carolina; The Armour Research Foundation, Chicago, Illinois; and several foreign installations.

Swimming Pool

The swimming pool reactors are so named because the reactor core is located near the bottom of a large pool of highly purified water approximately 20 feet deep. The core consists of a rectangular assembly of plate type fuel elements. These elements are known as the MTR type, since they were originally designed for the MTR reactor. Each plate of aluminum uranium alloy is clad with aluminum. Plates are made up into elements about 2 feet long with a cross section about 3 inches square. There are from 10 to 20 plates in each element. As in the other reactor types listed in this paper, the control rods consist of various geometric forms ranging from solid rods to flat plates of neutron absorbing materials. Control rods are normally lifted out of the core by means of magnets in contact with armatures attached to the rods. In event of a power failure or other operational problems, the magnet current is reduced and the control rods fall back under the action of gravity into the core.

The entire core assembly and the control rods are normally suspended from a bridge over the top of the pool. This bridge can be moved from one section of the pool to another. It

provides one of the most important and versatile features of the reactor.

Very often the reactor pool is divided into sections with a removable gate between the sections. It is thus possible to drain the water from either section for repair or maintenance operations. All of the normal operation of the reactor is plainly visible through the pool water, which acts as moderator, coolant, and shielding. The reactor can be operated utilizing convective cooling by the pool water, or it may be operated at higher powers using forced cooling. In that case the water is normally drawn down through the core and out of the pool proper by a pump. The downward flow is utilized because of the problem created by the existence of the 0.7 second short half life radioactivity due to nitrogen-16 formed in the core coolant flow. At higher powers this activity is brought too rapidly to the surface by convective cooling and forced, downward flow must be used.

Experimental beam ports and thermal columns are usually provided for in this type of reactor. These horizontal facilities normally exist on a sub floor at one end of the pool. In order to utilize these facilities the core is moved into a recess provided at one end. Some facilities have the thermal column and the ports located in different parts of the pool. All facilities make use of the fact that it is very easy to introduce samples and experiments through the water from the top of the pool. If it is necessary to prepare a complex experiment, it is possible to drain one half of the pool and to prepare the experiment in the dry half. After the experiment is prepared, the pool may be refilled and the core moved up to the experiment for operation. By moving the core away from the beam port position the radiation levels may be reduced to below safe tolerance and experiments may be easily changed and modified in any of the beam ports.

Except for special purpose facilities, the swimming pool reactors, in order of their criticality date, are located at: Oak Ridge National Laboratory, Oak Ridge, Tennessee; Pennsylvania State University, University Park, Pennsylvania; Naval Research Laboratory, Washington, D. C.; Battelle Memorial Institute, Columbus, Ohio; and the University of Michigan, Ann Arbor, Michigan. Several others are under construction at the present time.

H_2O-Tank Type

The core of this type of reactor is very similar to that utilized in the swimming pool reactor. The principal difference between the two types is that the pool, which has been described above, has been reduced in size to a small diameter tank. The effects of this change are to reduce the accessibility to the core, to reduce the flexibility obtained by being able to move the core freely, while at the same time the change has increased the possibility of providing additional facilities—perhaps up to twice as many—and it has increased the possibilities of going to higher powers and to higher fluxes. By proper design of transparent lids in the top of the tank it is still possible to observe operations of the core. Much of the possibility of introducing samples easily from the top is still retained. The number of horizontal research facilities available will normally be of the order of twice as many as in a swimming pool. Such reactors with proper heat exchanging equipment can be operated at powers sufficiently high to provide reasonable reactor component testing fluxes (greater than 10^{14}). Except for heat exchanging equipment, costs for a tank type reactor may not greatly exceed that of a pool type reactor with forced circulation.

Reactors of this general type in order of date of their critical operation exist at: Oak Ridge National Laboratory, Oak Ridge, Tennessee (LITR); National Reactor Testing Station, Arco, Idaho (MTR); Los Alamos Scientific Laboratory, Los Alamos, New Mexico (Omega West); and the Livermore National Laboratory, Livermore, California (LPTR). It should be pointed out that no reactor of this type has as yet been built in a university owned facility although several have been considered at one time or another.

D_2O-Tank Type

This type of reactor utilizes heavy water (D_2O) as both coolant and moderator. The fuel elements in those constructed to date have been of the general MTR type or cylindrical modifications thereof. Because of the high cost of heavy water ($28/lb.) and the possibility of loss by leakage, both of the currently existing designs utilize a heavy top shield of high density shielding materials rather than a deep tank of heavy water. This means that the actions within the core can not be viewed in this type of reactor. The reactor has a large available experimental volume which can accommodate perhaps two to four times as many experimental facilities as can be accommodated in a tank type light water moderated reactor. Because of the long thermal lifetime of the neutrons which exist in a heavy water moderated reactor it is slower in its response to sudden reactivity changes and hence is inherently a very safe reactor.

This type of reactor requires a complex process system and it is normally as much as a factor of two more expensive than a comparable tank type reactor. However, the cost per useful experimental facility may be even lower than that of a tank or pool type reactor, since so many more facilities are available. Reactors of this type exist at the Argonne National Laboratory, Lemont, Illinois; and the Massachusetts Institute of Technology, Cambridge, Massachusetts.

Critical Facilities

One other type which may someday become important in teaching and research is the critical assembly. The development of many of our science and engineering advances of the immediate past has centered in the universities. Unless the cost, the safety problems, and the government regulations prove to interpose too many obstacles, this may also happen in the nuclear reactor field.

In that case remote sites and critical assembly installations may prove of importance. However, this almost certainly will be done only at the most advanced levels and with the utmost precautions. Such a program should not be undertaken without very extensive prior experience.

Teaching Reactors up to 10 Kilowatts

Considerable interest has been developed in a reactor type which could be used for teaching purposes. In most instances some research, including activation of samples, can be done with these reactors, although they operate at relatively low power and hence low flux. The principal stimulus behind development of this type of reactor has been the Atomic Energy Commission's program of aid to engineering education. Grants have been given to cover the cost of construction for reactors whose power is up to 10 kilowatts. At least two versions of this reactor have been proposed at National Laboratories (The Argonaut at the Argonne National Laboratory and a plate type reactor proposed by the Oak Ridge National Laboratory) and at least three commercial groups have already built and delivered or

are prepared to deliver reactors which fall into this general classification.

All of these reactors appear to be safe and operable without major problems. It should be pointed out that even this type of reactor still requires a strong interest on the part of staff members of the university involved and also in general requires that the university be prepared to at least match the funds made available by the AEC. All of these reactors provide facilities for irradiation of samples and provide a complete control system. For the most part these reactors do not provide a means of observing the core during operation. This is because such a provision increases the cost considerably, since more shielding is required.

Commercial versions of a reactor simulator are also available. These units make use of analogue computers and electronic components to duplicate the control system and the neutron and process system responses of various types of reactors. They have useful teaching applications.

Power Levels

The power level at which the various types of reactors discussed above operate are limited in some cases by characteristics of the reactor type, and in other cases by the costs of going to higher power. In order to indicate the ranges of power available, power levels may be delineated in three different ways. The ultimate maximum power level is a somewhat hypothetical power beyond which it is believed serious technical difficulties may arise. However, this is not to say that reactors of these general classes can not be built above these power levels. The present maximum power level indicates the maximum power at which at least one reactor of each type has been operated in a routine manner, although in some instances the interval of time has been somewhat brief. The average power level indicates the level at which an average reactor of each class is currently being operated at this time.

A homogeneous reactor is limited in power because of the increase in the gas evolution as the power is increased. This problem can be overcome by pressurizing the system, but this makes the reactor much more complex and possibly more dangerous. In 1953 the group at Los Alamos associated with the Supo reactor reached the conclusion that it might be possible to design an unpressurized water boiler which would operate at powers of from 100–200 kilowatts.* Although such a reactor has not yet been built, it still seems feasible. Late information indicates that the Japanese water boiler designed in this country has been operated at 66 kilowatts on occasion. The average design power of the water boilers being designed and constructed in this country is 50 kilowatts.

Swimming pool reactors can be operated either convectively or by forced cooling. The LITR has been operated briefly convectively at 3500 kilowatts. Several of the swimming pool reactors in existence have been operated for short periods of time at 1000 kilowatts. All of the swimming pool reactors currently in operation have been routinely operated at 400 kilowatts utilizing only convective cooling. A power of 10,000 kilowatts can perhaps be reached when the swimming pool is cooled by pumping.* A limitation is placed on this system by nitrogen-16 activity at the water surface and by the necessity for either higher temperatures or excessively

* The author was a member of this group which operated Supo and studied water boiler designs before designing and constructing the Omega West Reactor.

* The consensus of opinion from those members of the Sub-committee on Research Reactors who are currently working with swimming pools.

large heat exchanger systems. While no swimming pool is currently operating in this country at 5,000 kilowatts, a version of the swimming pool designed in this country has been operated in Brazil at this power level. A number of swimming pools in this country are currently operating at the 1000 kilowatt level utilizing forced cooling.

The tank type reactor utilizing light water is limited in power by the problem of heat removal from the fuel element plates by the passage of the cooling water. The problem of heat removal from the reactor becomes difficult at a power level of about 10,000 kilowatts. The problem has been solved up to the level of about 175,000 kilowatts (ETR). At this level the rate of water flow in the core is very high and it is doubtful that the power can be raised much further without considerable redesign of the system.

The principal problem facing a university which might be considering this type of reactor is the cost of the process system necessary to achieve powers above, say, 10,000 kilowatts. Thus, as far as the university is concerned the limiting factor in this type of reactor is probably cost of the facility. While no reactor of this type has been constructed at a university site, it is probable that the reactor itself exclusive of building and operating at powers of 5000 to 10,000 kilowatts can be constructed for about $1,000,000.

The heavy water tank type reactor will also be limited by the rate at which heat can be removed from the fuel elements. In the present design form, with approximately half as many fuel elements as the tank type light water moderated reactor, the power level will be somewhat lower than that in the comparable light water tank type reactor—perhaps 30,000 kilowatts. However, if the system were redesigned there is no reason why more fuel plate cooling areas could not be provided and the reactor could be operated at much higher powers. The limits in this case are again those of cost.

The teaching reactor power level is limited by the AEC definition of a teaching reactor. This definition states that the power level will be less than 10 kilowatts.

Neutron Flux Levels

The neutron flux level in a reactor is closely related to the power of the reactor. It can be stated that the average thermal neutron flux in a reactor core is given approximately by multiplying the power in kilowatts by 2.6×10^{10} and dividing this quantity by the critical mass in kilograms. The powers given in the table are those which represent the central flux at the average power stated just above. This value will normally be somewhat higher than the value given by computation just outlined. It should also be realized that the flux in the reactor can be affected by the geometric arrangements, by the type and utility of the neutron reflector which surrounds the core of the reactor, and by the general core design.

The critical mass of the water boiler type reactor is in general quite low. It ranges from 0.8 kilograms (Supo) to approximately 1.5 kilograms. As a consequence its fluxes are approximately a factor of 2 higher than those of a swimming pool reactor at the same power.

A swimming pool type reactor varies considerably in its critical mass, depending on the reflector used. The BSF has a critical mass of 2.3 kilograms of enriched uranium with a BeO reflector and 3.5 kilograms with a water reflector. The Penn State and the Battelle Memorial reactors have critical masses of about 2.7 kilograms. The well reflected reactors will give

COMPARISON OF ENRICHED RESEARCH REACTORS

Type	Water Boiler		Swimming Pool	Tank-Type	
Moderator Reflector	H_2O Graphite	D_2O D_2O	H_2O H_2O	H_2O Graphite	D_2O D_2O
Neutron lifetime, m sec.	0.16	1	0.06	0.16	1
Max. reactivity which will not damage reactor	High	Very high	1.9%	3.8%	~10%
No. of seals for fission products	1	1	1	2	2
Max. practical flux	10^{12}	10^{13}	$\sim 10^{13}$	$> 10^{14}$	$> 10^{14}$
KGM U-235	0.8	0.8	3	3	1.7
Cost,* flux = 10^{12}	$120,000	?	$100,000	—	—
10^{13}	—	?	400,000	$ 600,000	$ 800,000
10^{14}	—	—	—	2,000,000	1,800,000
Rank (1 = highest)					
Relative safety	4	3	5	2	1
Economy ($\phi = 10^{13}$)	—	4?	1	2	3
Versatility	3	3	1	2	3

* Reactor only

approximately 1×10^{13} thermal neutrons/cm.^{2}/sec. at one megawatt power in the center at the point of highest flux.

The tank type light water moderated reactor will give approximately the same fluxes as are available in the swimming pool reactors. However, most tank type reactors will have better reflectors and will therefore have a somewhat lower critical mass and correspondingly a somewhat higher flux. The differences in flux levels between the swimming pool and the tank type reactor operating at the same power are normally not significant and special geometries and loadings will have much more importance than the type of reactor.

The heavy water cooled and moderated tank type reactor has a critical mass of between 1 kilogram and 1.4 kilograms of enriched uranium. Because of this low critical mass the thermal neutron fluxes in the heavy water cooled and moderated reactor will be roughly 2 to 3 times the fluxes in a swimming pool operated at the same power.

Teaching Uses

There has been considerable emphasis placed in the last year or so on the teaching uses of research reactors. Certainly if the atomic industry is to grow and flourish, universities of this country must accept the challenge of providing trained man power in this field. It can not be expected that this man power will be adequately trained unless at some time during the training period at least a portion of this group has access to laboratory facilities. This does not say that it is necessary to have a reactor to conduct an adequate nuclear engineering program. In particular, the existence of laboratory facilities in radiation detection techniques, reactor simulators, and other teaching aids such as subcritical reactors like the "pickle barrel" and graphite exponential can form a practical basis for a very strong nuclear engineering program.

As a teaching tool the reactor should be available to the students for large portions of the time, should be simple enough so that the principals can be clearly demonstrated

and understood, and if possible should have its principal parts visible and accessible to the students.

A number of generalizations can be stated concerning the use of reactors in teaching. First, the higher the reactor power, flux, and cost, the more likely it is that the reactor will be used for research purposes, and the less likely it will be used for teaching purposes. Second, types of research requiring long experimental runs such as neutron diffraction, radiation damage experiments, loops, etc. will conflict with teaching accessibility. Third, safety considerations such as higher power levels, availability of excess reactivity, site of the reactor, and other considerations will limit the student use of the reactor.

Reactors have been rated on an approximate scale in accordance with the value in teaching. These ratings are believed to be in accordance with the general feelings of the Sub-committee on Research Reactors for the National Academy of Sciences. The swimming pool convectively cooled is perhaps the best teaching reactor currently available. Because of the transparency of the water which serves as shield, coolant, and moderator, all of the principal parts of the reactor are plainly visible and can be observed in operation. The blue Chrenkov radiation can be seen and its relation with the actions of control rods is plainly visible. The control system is simple and its action is easy to explain and to observe. If the reactor is operated convectively at low powers and it is possible to start the reactor up and shut it down frequently, the reactor is very close to an ideal teaching reactor. The addition of forced cooling enhances its teaching usefulness. It allows the measurement of the thermal output of the reactor by means of recording the flow and the change in temperature of the coolant. On the other hand, as the reactor is brought to higher powers and fluxes and becomes more and more useful as a research reactor, the conflict between research and teaching interests becomes more and more favorable to the research side.

It is interesting to observe that one reactor (Penn State) which operates convectively frequently starts the reactor up and shuts it down and that the experience there with the teaching usefulness of the reactor has been very good. Another swimming pool reactor (Naval Research Laboratory) operating at a power of 1 megawatt has found that the experimental use of the reactor (5 ports utilized by neutron diffraction experiments) has precluded any frequent startups or shutdowns. While these two examples are not strictly comparable it is evident that a large program requiring long experimental runs will tend to conflict very much with the teaching purposes of a reactor. For this reason a forced cooling swimming pool type reactor has been listed as number 2 in teaching usefulness.

Teaching reactors themselves, because of their low power and neutron flux, will normally not be used for extended research experiments. Because of this, the teaching usefulness is enhanced. In this compilation they have been given a rating of 2 also because almost all of the currently marketed versions of this reactor have a closed top which precludes observing the actions of the core and the control rods. Those versions which allow the core to be viewed during operation would of course be ranked number 1 also. It should be pointed out that shielding sufficient to make a larger version with a visible assembly requires a larger building to house the facility. Thus the costs mount rapidly and very shortly it is no more expensive to build a swimming pool than it is to build a teaching reactor. At least one installation is considering

having two fuel loadings, one for teaching which would not be very radioactive, and one for research uses, which would be more radioactive.

The water boiler type reactor is ranked as number 3 in teaching usefulness. A very low powered version of this reactor with no cooling is marketed at present as a teaching reactor. The water boiler retains most of the teaching advantages of the so-called teaching reactors and combines them with more research usefulness. It is easy to start up and shut down this reactor and the reactor is safe. For this reason it makes a good teaching tool. On the other hand, one can get into some complexities with the more complicated cooling and recombination systems required in this reactor. It was therefore given the ranking of number 3.

The H_2O moderated tank type reactor will normally operate at higher powers and hence is under greater pressures to deliver continuous research fluxes. As such, its teaching usefulness is diminished. However, it is possible to have transparent windows in the top section of the tank and by this means to observe the entire action of the core.* In this sense it is almost as good a teaching tool as the swimming pool reactor. The accessibility to the top is more limited, but still not too difficult.

The tank type D_2O moderated reactor is useful for teaching purposes. It is planned to use it at MIT as a part of teaching courses which will give instruction in both reactor operations and in the uses of neutrons in research reactors. However, the complexities of the system, the pressures of research programs, and the location of the reactor all tend to cause the ranking of this type of reactor to be relatively low.

* The Omega West Reactor has such windows.

Research Uses

It is difficult to make a comparison between these reactors for research purposes, since some are limited to lower powers than others. Therefore, the reactors have been compared at a power of 1 megawatt (1,000 kilowatts) or at the maximum power available. This means that the water boiler is compared at 66 kilowatts and the teaching reactor at 10 kilowatts. Almost all of the reactors in the United States have some means of getting thermalized neutrons out to experimental positions. Almost all have some means of inserting samples into or close to the reactor core. And almost all have some means of getting a beam of neutrons out from the reactor core.

The heavy water tank type reactor is rated as number 1 for research uses since it has the largest high thermal flux volume available for research purposes and the highest thermal neutron fluxes. It now appears that for certain thermal and epithermal flux uses such as neutron spectrometers, the heavy water reactor can deliver even higher fluxes by means of special fuel element arrangements. Normally this type of reactor is not as good for reactor component testing as a comparable tank type H_2O type reactor, unless the samples are small and can be inserted within fuel elements, since the H_2O tank type has larger fast neutron flux volumes. Reactors can be used for experimental programs in neutron diffraction, fuel element development, neutron cancer therapy, activation of materials, biological and medical research, cross section measurements, loop experiments, and reactor physics measurements.

The H_2O moderated tank type reactor will normally have less than half the experimental facilities of the comparable D_2O reactor because of the

limited core volume. The same general classes of experiments can be done with either reactor, except that the H_2O reactor is not nearly so amenable to the modifications which make the D_2O moderated reactor so useful in neutron diffraction. In general, the fluxes at the same power are approximately a factor of two lower.

The swimming pool reactor will normally have perhaps half as many experimental facilities as the tank type reactor. However, it has more access available from the top and flexibility for the handling of large experiments such as shielding experiments and large bulk irradiation. Therefore, it must be ranked close in experimental usefulness to the tank type reactor. In fact there are no doubt many who will rank it as comparable or even superior to the tank type reactor. In general this ranking will depend upon purposes for which the reactor is intended.

Because of their lower powers and hence fluxes, the homogeneous or water boiler reactors and the teaching reactors must be given ranks of 4 or 5 respectively. Both of these reactors can still be utilized in activation analysis and for the preparation of samples. Because of its relatively high flux per unit power a reactor design has been made utilizing the water boiler as a source for a neutron cancer therapy facility.

It is interesting to note that to date three neutron cancer facilities have been planned. Each one utilizes a different type of reactor (Brookhaven-H_2O tank type, UCLA Medical School-water boiler, Massachusetts Institute of Technology-D_2O tank type). This situation is very typical. All of the reactor types can have beam ports, thermal columns, pneumatic sample changers, and other comparable facilities. These facilities are often easier to introduce into some types of reactors than others.

In practice most university groups to date have found little research interest on the part of physics departments except in the field of neutron diffraction. Most have found that there is a certain amount of inertia in building up broad experimental programs with a wide representation through the various departments of the university. Those groups which in general are interested include nuclear engineering, chemical engineering, electrical engineering, mechanical engineering, metallurgy, chemistry and radiochemistry, biology, medicine, and agriculture.

Conclusion

From this discussion it can be seen that the selection of reactor type and power level is a function of many variables. These include, site, funds available, and the requirements stipulated by the potential uses of the reactor. Although the difficulties of reactor selection, design, and construction are greater, the problem is much that of a man about to build a house. He must select a site to suit his needs. He must select a house to suit the site and his requirements. He must keep within his financial limitations. He must think ahead in terms of his future family size and development.

The approach to the reactor problem should be much the same as that of the potential home owner. A thorough investigation of all of the possibilities, including site, reactor type, power and finances, should be made. A survey of possible uses and users should be undertaken. The nucleus of an intensely interested group should be formed if there are strong indications that a reactor should be constructed. From that point on, each group must make its own choice. It is to be hoped that the group will choose wisely, as it must live with its choices for many years.

SAFETY AND SITE SELECTION

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Paper presented at the 1958 Annual Meeting of ASEE. This paper was one of four presented in a program organized by the Subcommittee on Research Reactors of the National Research Council. Recommended by the Nuclear Committee.

Introduction

There are probably as many different opinions on reactor safety and how to achieve it as there are people operating reactors. Fortunately, there are certain basic rules that most of us follow. We realize that every possible precaution must be taken to prevent an incident and the subsequent release of large amounts of radioactive material to the surrounding area. It is also true that a serious incident at a university would, most likely, make it even more difficult, if not impossible, to operate a research and training reactor on a university campus.

An important consideration for any university in obtaining a research reactor is the selection of a suitable site for a reactor. I wish that I could, at this point, give you a set of rules or a formula that you could take with you and apply to several locations on your campuses to determine the best location from a safety viewpoint for a research reactor. If such a set of rules were available, you could also compare your proposed reactor location with reactor locations already established on other university campuses. Unfortunately, no such set of general rules exists at this time. Dr. Gomberg at the University of Michigan, our group at the Pennsylvania State University, and other groups such as the insurance companies, have been trying to formulate such a set of rules, but much work still remains to be done to accomplish this objective.

Site Selection and Containment

In general, there are really three approaches to the site selection problem. The first is the infinitely large exclusion area such as the AEC uses at its National Reactor Test Station at Arco, Idaho. The second is the complete containment, no exclusion area, such as that used at Massachusetts Institute of Technology and the Armour Research Foundation. These two reactors, incidentally, are located in heavily populated cities. The third is, of course, a combination of the first two —some exclusion area and some provision for containment. The third approach is usually the only reasonable one for most universities to take, especially since the reactor must be near, or better still on the campus to be most useful to the faculty and students.

Complete containment is usually quite expensive and it is also very difficult to prove that one has satisfied these requirements. Of course, the requirements of the type of containment depends upon the type of reactor to some extent. For example, the M.I.T. reactor is a force-cooled heavy water moderated type, completely sealed in a closed loop cooling system. A reactor of this type takes less area in square feet than some other types and thus it was convenient to construct a gas-tight steel shell containment vessel to cover the reactor area. It was also necessary in this case since the reactor is located in a highly populated area. However, for a "swim-

ming-pool" reactor this steel containment vessel type of construction could become quite expensive, especially for large pools. Thus, schools such as the University of Michigan, with a "swimming-pool" reactor, have used reinforced concrete construction to cover a much larger area including their pool and laboratory facilities. Some radiation shielding is also afforded by this type of construction, in addition to being essentially gas-tight. The "swimming-pool" reactor at the Pennsylvania State University is not housed in a gas-tight building, but is in an ordinary building of steel beam and insulated metal siding. This structure is, however, located on one edge of the campus away from dormitories and the town. This is, of course, an example of using predominantly exclusion area design.

It is also necessary to know just what kind of a risk is involved and how extensive any accident might be, before one can cope with it in terms of building and facility design. Many complications are involved in ascertaining the maximum plausible damage resulting from a reactor accident. A few years ago we considered that the worst possible case, a complete vaporization or melt-down of the reactor core, and a resulting radioactive cloud, was the maximum creditable accident. However, we now know from various tests conducted by the AEC and from a detailed study of data from the two or three reactor incidents that have taken place that this is not realistic. It now appears that only about ten per cent of the fission products, and primarily only the volatile fragments, are released in the melting of the fuel elements composing a reactor core. Thus, the maximum creditable accident based upon our present knowledge is far less of a catastrophy than was previously supposed. So, the site and containment problem reduces to assuming the maximum creditable accident that is acceptable to the AEC. From this information one must then determine what pressure the containment vessel would have to stand, and how one would eventually clean up the mess safely.

For instance, considering the case of exclusion area only, the following questions would have to be answered: how much area would be necessary? how many temperature inversions would be expected per year? how much rainfall would there be per year? what is the prevailing wind direction, and is it towards a community? are there any streams or rivers in the immediate vicinity of the proposed site? After these questions have been answered, it must be shown that the proposed reactor site will be reasonably safe. The meteorological portion of this study is well defined and can be carried out without difficulty, especially if good meteorological data have been collected on your campus for years. The real problem, of course, is the input data to all of the subsequent calculations of the amount of radioactive material that will be released. There is an extremely wide latitude of basic assumptions and there are many uncertainties and unknowns. Our subcommittee is planning to investigate this area in detail and, if possible, to standardize the data used to calculate the maximum creditable accident for various types of reactors of interest to universities.

Waste Disposal

Another factor that must be considered in establishing a research reactor on a university campus is the waste disposal problem. The magnitude of this problem depends upon the type of reactor, the reactor power level, the type of research programs, and the supporting facilities. Generally, the homogeneous reactors will require a more elaborate disposal sys-

tem and a larger area than most of the heterogeneous solid fuel reactors.

For instance, the Pennsylvania State University research reactor has been in continuous operation for the longest period of time of any reactor on a university campus. The fission product activity from this reactor is permanently contained in the fuel elements and will eventually be returned to the AEC. Thus, our main concern is with samples and apparatus which are irradiated in the course of experimentation. These must, of course, be either stored or disposed of at the conclusion of the experiment. Some of the samples can be flushed down the drain because of the small amount of remaining activity, but others must be kept for a period of time. At Pennsylvania State University we have established a fenced and posted radioactive storage area on University farm land. The storage facilities consist of six 500-gallon septic tanks placed in a circle with a twenty-five foot diameter. We started filling one tank at a time, and after the radiation level has increased to a few hundred milliroentgens per hour for that tank we started using the next tank, etc. As yet we have not completed the circle, but I imagine that by the time we do, we will find that the activity of the first tank has died away. We have also designed and are building an incinerator with a water scrubber for combustible waste. This disposal area has the unique feature that it can be picked up and moved to another site if so desired. This is a desirable feature for universities faced with the present expansion requirements.

In addition to a disposal area, some means of storing the pool water is occasionally needed for "swimming-pool" type reactors. Some facilities are equipped with hold-up tanks that will hold all of their pool water. This can represent quite a financial savings when it is desired to save the demineralized water. In addition, if the water should become contaminated, such a storage system would be invaluable. However, hold-up tanks are quite expensive and thus some university reactor facilities have been and will be forced to operate without them.

Organization and Administration

Another safety feature that I would like to discuss briefly is the organization and administration for safety. In the opinion of our subcommittee on research reactors, additional safety can be achieved by properly organizing and administering a reactor facility. It is generally agreed that the operations staff should be separate from the research staff. However, there is no reason why a man cannot be on the research staff part of the time, and the operations staff the rest of the time, provided his duties are well defined in each case. Furthermore, all members of the reactor operations staff should be full-time university employees. From the experiences of various members of the subcommittee, it is felt that the university does not have sufficient control of graduate students to risk using them in reactor operation; in fact, this practice could prove quite hazardous.

A few examples of the way presently operating research reactors are administered is pertinent at this point. The Pennsylvania State University Research Reactor is administratively under the Dean of the College of Engineering and Architecture. Although the reactor is under the College of Engineering and Architecture, every effort is made to make the reactor available to any one on the University faculty. Thus, in practice it is a University-wide facility. The operating staff of the reactor consists of a Director, an Assistant Director, two reactor supervisors, three operator- technicians, one electronics technician, and a secretary-receptionist.

Another example is the University of Michigan research reactor, which is under the Phoenix Project, a University-wide independent research organization. In this organization the reactor operation is under the immediate direction of a Supervisor, and the health physics is under the immediate direction of the senior Health Physicist. These two groups are coordinated under the Laboratory Director of the Phoenix Project. The reactor operations group is composed of the Reactor Supervisor, the Associate Reactor Supervisor, and several reactor operator-mechanics.

In both examples cited, the senior level people assume some teaching obligations. The health physics group at neither of these universities reports administratively to the Director of the reactor, thus making them more independent in their decisions regarding radiological safety. Also, in both of these universities a review committee system is used to review and recommend the feasibility of conducting experiments that may have been thought to be hazardous. However, at Pennsylvania State University the final decision rests with the Director. At the University of Michigan the final decision rests with the committee.

Inherent Performance and Safety Characteristics of the Reactor

It is an assumed fact that a reactor can malfunction occasionally, and in this respect they are no different from other machines. Among other things, such malfunctioning can result from human errors, equipment failures, design errors, and acts of God. Because these things can happen, the multitude of safety features are necessary. Thus it is also important to apply as many additional safety measures as is consistent with retaining the reactor's usefulness.

It is obvious that trained and competent people must be available for reactor operation. We have previously mentioned the techniques used in administering a reactor for safety, and it suffices to say that many safety devices can be built into the reactor control system. In addition to all of these features, there are certain inherent safety features basic to each type of reactor. All reactors that are now seriously considered as useful research reactors have a negative temperature coefficient in the operating range. This, of course, causes the reactivity to go down as the temperature in the reactor core goes up. At high reactor power levels, xenon and samarium poisoning causes a reduction in reactivity. Other features of value, particularly in the homogeneous reactors, are the expansion of the reactor fluid which forces some fluid out of the reactor core reducing reactivity, and the boiling of the reactor fluid resulting in a decrease in reactivity. In regards to the "swimming-pool" type of reactor, a power excursion will result in an increased temperature of the water coolant, producing boiling and subsequent removal of the reflector, thus shutting the reactor down. By no means do these comments cover the reactor safety topic completely, but they should serve to point out that reactors are inherently safe when properly handled and suitably located on a university campus.

MEETINGS

The annual meeting of the Atomic Industrial Forum is scheduled for November 9–12 at the Shoreham in Washington, D. C.

The American Nuclear Society will hold its winter meeting in Detroit, December 8–10.

PURPOSES AND PROCEDURES IN THE LICENSING OF REACTOR FACILITIES

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Presented at the Annual Meeting of ASEE. Recommended by the Nuclear Committee. The Commission is currently preparing a revision to Part 50 of its regulations which will delineate more precisely the information to be included in license applications for reactor facilities. The requirements of the revised regulations will be substantially the same as those discussed in this article.

Universities and colleges contact the Atomic Energy Commission in four major areas when they undertake to build a training or research reactor:

1. financial assistance,
2. fuel allocation and fuel reprocessing,
3. licensing for construction and operation,
4. inspection, both initial and periodic.

The financial grant policies of the AEC have been described at numerous conferences and meetings, and you probably know that George Packer in the AEC's Division of Reactor Development is the person to contact on these matters.

The Commission's policies on making fuel available to universities, agreeing to reprocess fuel without charge, and on furnishing neutron sources are also well known. Mr. Packer also is the AEC contact in this area.

It seems to be less well known how to obtain a construction permit for a reactor, what the requirements are for an operating license, and what is the relationship between the inspection and licensing procedures. Perhaps I may be able to give you some degree of clarification on these matters.

Basically, licensing and inspection of reactors by the Federal Government is for the purpose of giving maximum assurance of the safety of these facilities. The major objective of the activities leading to the issuance of an operating license is an evaluation of the potential hazards of the proposed facility and of the adequacy of the safeguards provided. The purpose of the inspections of the reactor during its construction, just prior to its initial operation, and at periodic intervals thereafter is to assure that construction and operation are in accord with the specifications and procedures previously agreed on as being acceptable, and to assure that satisfactory methods of supervision and operation are being followed.

Licensing of a reactor facility is accomplished in two major steps: the first, usually quite early in the life of the project, when a construction permit is granted; the second, after construction is completed, when an operating license is issued.

The formal beginning of the licensing process occurs when the university or college applies to the Commission's Division of Licensing and Regulation for a construction permit for the reactor facility. Prior to this, if necessary or desirable, there may be numerous conferences between the applicant and members of the Division's staff on procedures, contents of the application, etc. In order for a construction per-

mit to be granted, the commission must find "that it has information sufficient to provide reasonable assurance that a facility of the general type proposed can be constructed and operated in the proposed location, without undue risk to the health and safety of the public." It should also be noted that the Commission must find that there is reasonable expectation that information that is necessarily missing from the application as submitted and amended will be supplied prior to the time that operation is expected to commence.

The Preliminary Hazards Report

The Commission arrives at this decision largely on the basis of information presented by the applicant in a Preliminary Hazard Report. Two essential functions must be accomplished by this report.

A. The conceptual plan and anticipated features of the facility must be described in sufficient detail to permit estimation therefrom of the hazards which might arise through operation of the facility, and of the adequacy of safeguards of the public against these hazards, and

B. the applicant's own analysis of these hazards must be given, together with reasons for his belief that adequate safeguards will exist for the protection of the public against these hazards.

Since design details and anticipated behavior characteristics normally are not confidently established at this time, it may not be possible to present a firmly based description of the credible potential hazards expected to exist. Generally, therefore, the applicant describes some *upper boundary for the hazards,* beyond which no credible hazards would be expected to fall when later systematic analyses can be made, and shows that even for this upper limit of hazards adequate safeguards for the protection of the public have been incorporated.

From analysis of the Preliminary Hazards Report, the Commission will appraise the hazards which may potentially exist in a facility of the type proposed, and determine the adequacy of safeguards inherently present or incorporated by design against these hazards. To accomplish this, examination is made of the hazards and safeguards and evaluation presented by the applicant and, where necessary, independent analyses, estimations and calculations are made. Therefore, the conditions, assumptions, bases, and methods of analysis used by the applicant in arriving at the magnitude and consequences of hazards should be sufficiently described to permit their clear comprehension. Further, the pertinent features of the site and of the facility should be quantitatively described so that independent evaluation of the attendant hazards and consequences thereof can be made.

To accomplish the intended functions, the Preliminary Hazards Report should contain four principal components:

1. *A description of the proposed site.* The objective here should be to give a complete quantitative description of all environmental features relative to safety (or hazard) of the facility: the size and location of the applicant's property holding, the position of the facility on the property, population and industrial distribution in the surrounding areas, and relevant features of pertinent meteorology, hydrology and seismology. It should be noted, however, that a simple tabulation of these environmental data is not, *per se,* sufficient. There must be, in addition, a brief summary of synthesis of the information, including identification of the significant features, favorable or unfavorable, with respect to the safety aspects of the

proposed facility. Discussion of the relevance of these environmental data to the safety of the public may be included in the fourth part of the report, mentioned later.

2. *A description of the reactor.* The general features of the reactor including purpose, power level and general plan of utilization should be described. Details of the design or of the structure may be omitted unless they are pertinent to the over-all safety considerations. For example, only the functional features and a block diagram of the instrumentation are needed at this stage. All nuclear and physical data essential to potential hazards (e.g., dimensions, expected fuel loading, reactivity values, temperature coefficients, thermal features of the fuel) should be stated numerically, and an indication of the accuracy of the estimates given. Shielding, reactor experimental facilities, cooling provisions and instrumentation are considered part of the reactor.

3. *Description of the auxiliary systems, facilities and reactor building.* The conceptual plan of the facility should be delineated fully, with particular emphasis on the features relevant to safety: dimensions, functional arrangement of the building, containment specifications, plans for ventilation and waste disposal, and other auxiliary systems and their potential interactions with the reactor. Again it should be noted that presentation of these data as independent and unrelated tabulations may not achieve the objective of the report. Where possible, the applicant should identify and summarize particularly significant features or relationships of the safety aspects of the facility where this would facilitate understanding of discussions presented later in the report.

4. *Discussion of potential hazards.* Potential hazards which could arise from operation of the proposed reactor facility should be identified and their consequences analyzed. Discussion should lead to a set of assumptions which are realistically linked to the anticipated characteristics of the reactor and the conceptual design of the facility which would result in an accident having consequent damages not expected to be exceeded by any other accident arising out of any other credible circumstances. Once the assumptions which could lead to this accident have been defined, rigorous and complete analysis should be made of the consequences, both to the operators of the facility and to the inhabitants of the surrounding public areas. Relevant data from the site and facility sections mentioned previously should be included in the analyses. A summary of conclusions should show clearly the applicant's estimate of the potential hazards, particularly the public hazards, which could result from operation of the proposed facility.

The applicant's presentation in the Preliminary Hazards Report of the site, reactor, and facility descriptions and his analysis of the potential hazards should be so made that the Commission can understand the assumptions and methods used in arriving at the conclusions reached, and also can make independent analyses of the hazards where it might so desire. To achieve this, the Preliminary Hazards Report may in some cases need to be only a dozen or so pages in length, while in other cases a great deal more than this may be required. Where a relatively simple or well-proven low power reactor in a highly favorable location is proposed, it may be possible to give the necessary descriptions, establish an upper limit of hazard, and demonstrate that no significant consequent harm would be expected therefrom in a relatively short report. In the extreme case, it may even be possible to grant approval for operation at the construction permit stage, subject only to confirmation in

writing that the facility has been constructed as anticipated. In other cases, particularly for reactors having large fission product inventories, marginally acceptable locations, or controversial or little understood characteristics influential in the safety behavior of the reactor, detailed and complete analyses must be made. In these cases, it may be necessary for the Commission staff to hold numerous conferences with the applicant for clarification of issues, to seek the assistance of advisors and consultants, or even to request experimental elucidation of pertinent features, before a decision on the "reasonable assurance of safety" can be reached.

Significance of a Construction Permit

It should be noted that a favorable decision on any proposed facility and the subsequent issuance of a construction permit does not impose on the Commission an obligation for eventual approval for operation of the facility when construction is completed. Issuance of a construction permit does indicate that, in the opinion of the Commission, there is reasonable assurance that a facility of the general design concept proposed can be operated in the proposed location in such a way that undue hazard to the health and safety of the general public will not result. Further, this action may be taken to imply that there is a reasonable probability that the constructed reactor will be found acceptable from a safety standpoint, and, if this turns out to be the case, the eventual request for an operating license for the reactor will be granted. The final decision, however, on the adequacy of the safeguards to the public health and safety in the completed reactor must rest on analyses and evaluations made at that time, and is not prejudiced by prior decisions which may have been made on the expected eventual safety of the project in question.

When a reactor facility has been completely designed and construction has progressed to such point that the time for initial operation approaches, application for an operating license should be made. For such license to be issued, the Commission must determine from a complete investigation and appraisal that there is reasonable assurance that the facility, *as designed and constructed, and as proposed to be operated in the location existing,* will not result in undue hazard to the health and safety of the public.

The Final Hazards Summary Report

The Commission reaches a decision on this matter largely on the basis of cumulative information presented by the applicant in the Preliminary Hazards Report and in a Final Hazards Summary Report which accompanies the request for an operating license. This Final Hazards Report, which may consist of a single document or of several documents presented over a considerable period of time, constitutes a part of the formal application for an operating license, and becomes a part of the public record.

The purpose of the Final Hazards Report is to present a description of the facility as actually designed and constructed and a description of the anticipated plans and procedures for operation, together with a composite body of convincing evidence that operation as proposed will not unduly endanger the health and safety of the public. Material presented earlier in the Preliminary Hazards Report, where it is still valid, need not be repeated. However, where deviations in plans have occurred from those originally conceived and described, particularly if elements of safety are involved, these should be appropriately described. Reference should be made to relevant experimental or theoretical

clarification of safety issues which may have occurred subsequent to presentation of the Preliminary Report; to changes in components or systems arising from safety considerations; to justifications, foundations and analyses leading to final choices of safety features or components; to estimated consequences of potential hazards still existing; and to any new information which has been developed and is relevant to the safety of the facility. The over-all emphasis in this report should be on those aspects of the facility as constructed and for the plans for operation as anticipated which bear on the safety of the facility.

Thus, in the Final Hazards Summary Report the applicant establishes his own evaluations of the hazards which might arise from anticipated operation of the constructed facility, together with the basis and analyses which lead to this evaluation and sufficient information to permit the Commission to make an independent appraisal of the ultimate safety. To achieve this, the Final Hazards Summary Report usually contains four component parts:

1. *Description of the facility as constructed.* Attention should be given to features different from those originally described, with complete details, numerical and quantitative as appropriate, on features and components involved in the safety aspects of the facility. For example, the basis of specifications of building containment should be given along with justification for believing that the building as constructed will conform with these specifications.

2. *Detailed description of the reactor.* All characteristics of the reactor itself as finally designed and constructed are essential to evaluation of the over-all safety. Quantitative description of the physical, nuclear, thermal, hydraulic, and mechanical features and characteristics should be given. Description of the instrumentation and safety system should be given, and the bases for the final choice of performance specifications, and the functions to be performed.

3. *Administration, organization, plans and procedures.* Particular emphasis should be given to the organizational structure of the operating staff, the principal ground rules and policies of operation, and the plans and procedures to be followed in case of accidents or emergencies, insofar as these relate to safety and protection against the consequences of malfunction or misoperation.

4. *Final estimate of hazards and safeguards.* As the plant is finally completed, re-examination should be made of the potential accidents which could occur, including re-appraisal of hazards arising from the accident considered to be the maximum credible for the facility. It must be shown that adequate protection of the public exists even for this accident.

Thus, the Final Hazards Summary Report should be so presented that the Commission can clearly understand the specifications, bases, and methods used by the applicant in arriving at the conclusion that adequate protection of the public is provided against hazards which might arise from operation of the facility. In addition, sufficient information should be included on essential details to permit independent evaluation of the crucial safety aspects.

No sharp line can be drawn between what should be included in the first report and what in the second. In some cases, where essential features can be firmly fixed early in the project, much of the total information can be presented in the Preliminary Hazards Report, and relatively little in added descriptions, revisions and re-appraisals will be required in the

Final Hazards Report. In other cases, where extensive portions of the design are not known at the start of construction, or research and development is required during the construction period, the Final Hazards Report must be a great deal more inclusive.

The essential objective toward which both the Preliminary and Final Hazards Reports must be oriented is the presentation of evidence and information which will permit the Commission to decide whether or not there is reasonable assurance that operation of the facility at the site selected will not present undue hazard to the health and safety of the public.

Inspections

Inspections of the facility once construction has commenced may be made at any time. The Division of Inspection of the Commission, of which Mr. Curtis Nelson is Director, is responsible for making these inspections to assure that the reactor is being or has been built in accordance with specifications agreed on in the hazards evaluations, that approved construction techniques are being followed and applicable code requirements being met, and that acceptable methods of supervision and procedure in operation of the facility are being followed. There is one particular time at which all facilities are inspected, namely, just prior to initial operation. A satisfactory report on this inspection is a prerequisite to issuance of an operating license. All other inspections are scheduled at the discretion of the Inspection Division, and as specific situations may warrant.

Standards and Criteria

Hazards evaluations must be made on a case by case basis, although certain patterns are beginning to emerge, and we are now trying to develop general guides in our evaluations of reactor facilities.

We are now tentatively using two basic standards for determining the acceptability of radiation exposures, and from these proceeding to establish a consistent pattern insofar as this is possible. These basic criteria are:

1. for normal operations, the effluent streams (atmosphere, surface, subsurface) must be such that radiation levels at the site boundaries and beyond do not exceed maximum permissible levels for continuous exposures, and

2. in emergency situations, the quantities of radioactivity which would be released beyond the site boundary, for even the worst accident whose occurrence is considered credible, must be such that possible doses to people would not exceed a maximum emergency dose.

The permissible levels of radioactivity which may be *routinely* and *continuously* released into the air, water, or soil now observed by the AEC are described in Part 20 of the Commission's regulations (The National Archives of the U. S., Federal Register, Vol. 22, No. 19, Jan. 29, 1951). These levels are based on the contents of National Bureau of Standards Handbook 52, which were prepared by the National Committee on Radiation Protection, and are compatible with the recommendations of the International Committee on Radiation Protection. Part 20 also specifies the levels of external radiation permitted to individuals from routine operations of a reactor facility. These levels are also based on the recommendations of the International Committee on Radiation Protection as described in Handbook 59 of the National Bureau of Standards. This regulation established the basic permissible external exposure level for operative personnel at 300 mr/week of whole body radiation.

For a given reactor project to be considered acceptable, the routinely

released radioactive effluents expected therefrom and the exposure level of individuals from external radiation from the effluents must, upon examination, be judged to fall within the specifications of Part 20.

There is no officially adopted accidental or emergency once-in-a-lifetime exposure dose. The preliminary statement of the National Committee on Radiation Protection, contained in the Addendum to Handbook 59, contains only this tentative recommendation on emergency doses: "an accidental or emergency dose of 25 rems to the whole body, occurring only once in the lifetime of the person, shall be assumed to have no effect on the radiation tolerance status of that person."

Nevertheless, in evaluating the suitability of a given site for a proposed reactor facility, one must have some such guidance in deciding what exposure level beyond the site boundaries would be considered tolerable in case the maximum credible accident should occur. Therefore, the 25 rem whole body emergency dose is being used as a design guide by the AEC in evaluating the acceptability of reactor projects.

It should be understood, however, that this criterion does not have the force of a formal regulation, as is the case with limits of exposure from the routine operation of reactor facilities, and is merely used as a guide in the evaluation of hazards by the Commission. These two limits for exposure during routine and accidental conditions, however, do give the broad limits on which the acceptability of the design of reactor facilities is determined by the AEC.

NUCLEAR M.S. DEGREE ADDED AT MISSISSIPPI

The Board of Trustees of the Institutions of Higher Learning of the State of Mississippi recently approved the awarding of a new graduate degree at the University of Mississippi—the master of science degree in nuclear engineering.

The program of studies leading to the award of the new degree will be administered by the Department of Chemical Engineering and will be open to all qualified students.

At the conference on Engineering Education and Nuclear Energy —which ORINS conducted for the Atomic Energy Commission at Gatlinburg in 1956—the feeling of leading educators was that undergraduate instruction in nuclear engineering should be incorporated in recognized undergraduate engineering curricula.

In keeping with this view, no undergraduate degree in nuclear engineering will be offered at the University of Mississippi. New courses of instruction, however, have been set up by the Department of Chemical Engineering, and will be available to all science and engineering undergraduates who have the required prerequisites.

REACTOR COSTS

H. J. GOMBERG

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Presented at the 1958 Annual Meeting of ASEE at Berkeley. One of four presented in a program organized by the Subcommittee on Research Reactors of the National Research Council. Recommended by the Nuclear Committee.

One of the characteristics of the reactor field has been the steady and rapid increase in construction cost figures. Only part of this rise can be attributed to the increasing price index. Most of it has come from experience with building reactors at non-A.E.C. installations where all materials, supplies, services and know-how must be brought in. In addition, for total project planning there are the costs of planning and design which are often overlooked. To this must be added the costs of negotiation with the Atomic Energy Commission and possibly local health and safety authorities. Finally, a reactor as a reasonably large and complex machine requires a continuous expenditure of effort and money just to keep it in operation, independent of the use to which it is put.

Most of the available information on research reactor costs at non-A.E.C. installations comes from projects which started before the present reactor manufacturing industry existed. In fact, today's prices are based to some extent on the better experience encountered by companies and individuals in building some of these projects. Therefore, even this experience cannot be taken as completely representative of today's construction costs. On the other hand, we can expect design costs to drop somewhat and reliability of the equipment to increase in the future.

For purposes of this presentation, the matter of costs has been split into three categories:

a) Planning
b) Construction
c) Operation

The data in the following tables have come largely from the record of the meeting of the Subcommittee on Research Reactors of the National Research Council held in Ann Arbor, Michigan, on March 28 and 29, 1958. Projects being planned now were not included, because the experience with them is as yet incomplete. The methods of cost analysis and the items included vary somewhat with each project. However, by collecting representative data, the costs by almost any method of analysis can be ascertained.

Planning

Planning is one of the more difficult functions to classify and estimate. In some places, very sophisticated resident advice is available because a faculty or staff member has worked on similar installations at a government laboratory. Others must resort to self education through travel and study, the use of consultants, and reliance on the freely proferred assistance of the newly developed research reactor construction industry.

In any case, it is essential that very careful consideration be given to the integration of the facility with existing research facilities or a deliberate deci-

TABLE I

DESIGN AND PLANNING COSTS FOR SOME TYPICAL UNIVERSITY AND PRIVATE RESEARCH REACTORS—INCLUDING HOME STAFF COSTS DURING CONSTRUCTION

Location	Type	Rating	Date Planning started (Conceptual)	Extent of Planning of Home Staff	Remarks	Cost of Planning
Battelle Memorial Institute (Ohio)	Swimming pool	1 M.W.	1953	Preliminary and conceptual	Detailed design provided by vendor as part of contract	$53,000
Massachusetts Institute of Technology	Heavy water Heterogeneous	1 M.W.	1954	Preliminary and design drawings. Detailed specifications drawn for bidding	Manufacturer made own shop drawings. Also retained architect for enclosure	$120,000 ($160,000 to end of construction)
Naval Research Laboratory	Swimming pool	100 kw	1952	Preliminary and final working drawings	Designed for construction in own shops	$100,000 (estimated)
Pennsylvania State University	Swimming pool	100 kw	1952	Preliminary and final working sketches	Built at own shops. Designed to extent needed for personally supervised construction	$14,352
University of Michigan	Swimming pool	1 M.W.	1952	Preliminary and conceptual ($51,952)	Detailed design of reactor and building put out on bid. Costs: Reactor $ 8,912 Building $46,395 $55,307	$ 51,952 55,307 $107,259

sion taken to make the reactor laboratory totally independent, with the obvious consequences in cost.

The reactor itself should be treated simply as a device capable of providing radiation useful in a radiation research program and as a device through which some of the basic problems involved in controlled release of fission energy can be studied.

Table I covers, for the installations listed, the known amounts that were spent before start of actual construction. In some cases, however, it includes continued supervision and liaison during construction. This must be done on newly designed units to insure the building of what had been planned.

In the case of Michigan, planning included the preparation of detailed working drawings by design contractors, which drawings were then used as the basis of obtaining competitive construction bids. In other cases as at M.I.T. detailed shop drawings were prepared by the contractor, based on a previously drawn set of working drawings prepared by M.I.T. staff members.

At Pennsylvania State, there was supervision by highly experienced personnel, with all machine work being done primarily from sketches and directly under the supervision of the responsible faculty members.

At N.R.L. design work was done at the laboratory followed by construction of equipment in laboratory shops, while at Batelle Memorial Institute, working designs were prepared as part of the contract, after the type of reactor had been selected and its general characteristics determined by Batelle personnel. In every case determination of the type, rating and overall characteristics of the reactor are the responsibility of the school or laboratory personnel. How much more is done locally depends on the knowledge of this local group.

TABLE II

CONSTRUCTION COSTS

Does not include all home staff costs where reactor was built by Contractor

Location	Type	Rating	Contract-Coverage	Contractor	Dates		Remarks	Cost
					Start	Completion		
Battelle Memorial Institute	Swimming Pool	1 M.W.	General	B.M.I.	Aug. 1955	Oct. 1956		
			Design and construction of instruments, controls, bridge and core	A.M.F.				$77,000
			Design and construction of cooling system	A.M.F.				48,000
			Design of pool, shield and embedments	A.M.F.				
			Construction of building and pool	Elford			Building 70 × 110 × 50 block and metal siding	475,000
			Construction of embedments (Thermal Col., Beam tubes)	B.M.I.				77,000
			Site improvement					30,000
							Total	$737,000

TABLE II—*Continued*

Location	Type	Rating	Contract-Coverage	Contractor	Dates		Remarks	Cost
					Start	Completion		
Mass. Institute of Technology	Heavy water Heterog.	1 M.W.	General	A.C.F.	1956	1958		$2,200,000 (without lab)
			Reactor and reactor enclosure				Lab building and site $250,000 Lab building renovation $250,000	
Naval Research Laboratory	Swimming pool	100 kw	General (reactor built primarily by local personnel)	N.R.L.	1954	1956	Can be brought to 1 M.W. by additional expenditure of $63,000	
			Reactor, bridge, core plate, plumbing, hold up tank, beam ports, water gate, electronic controls					313,000
			Reactor connected auxiliary equip. such as monitors, plug handling gear, instrument bridge, pneumatics test electronics					108,000
			Hot cell as part of reactor installation					110,000
								531,000
							Building reconstruction for balance of total of about 1.1 million dollars	
							Total	$1,100,000

TABLE II—*Continued*

TABLE II—*Continued*

Location	Type	Rating	Contract-Coverage	Contractor	Dates		Remarks	Cost
					Start	Completion		
Penn State University	Swimming pool	100 kw	General	Penn. S.	1953	1955		
			Pool				(Not completed)	32,450
			Building				3,800 sq. ft.	134,483
			Control system and special components	L & N				76,000
			Beam ports, etc.	Penn. S.				24,000
			Land improvement	Penn. S.				26,675
							Total	$293,608
University of Michigan	Swimming pool	1 M.W.	General	U. of M.	Feb. 1955	Sept. 1957		
			Building and pool	Jeffers & Dyer				$574,273
			Reactor (base price, thermal column and beam ports)	Babcock & Wilcox				181,310
			Reactor instrumentation	L & N				45,000
			Cooling system	B & W				46,319
			Special facilities (fast pneumatic, transfer coffin and part cost of hot cell)					105,495
			Site improvement	U. of M.				17,082
							Total	$869,499

							Total	$1,100,000

TABLE III—ANNUAL OPERATING COST

Basic expense only—no research costs included

Location	Type	Rating	No. of Shifts	No. of Days per Week	Personnel	Time Fraction and Other Duties	Special Costs
Battelle Memorial Institute	Swimming pool	1 M.W.	3	6	Operating Supervisor	1	Amortization $70,000
					Assistant Supervisor	1	Fuel 4,000
					Operators and Technicians	9	
						11	
					Cost	$60,000	Maintenance and operation (not classified) 66,000
						Total	$200,000
Mass. Institute of Technology	Heavy water Heterog.	1 M.W.	3	5	Lab Director	½ (with teaching)	
					Gen. Supervisor	1	
					Shift Supervisors	3	
					Business Manager	1	
					Shift Operators	3	
					Health Physicist	1	
					Secretaries	2	
					Electronics Maintenance	1	
					Mechanic	1	
					Mechanical Designer	1	
						14½	
					Cost	$100,000	Insurance $20,000
							Electricity 55,000
							Maintenance 80,000
							155,000
						Total	$255,000

							80,000
							155,000
						Total	$255,000

TABLE III—*Continued*

Location	Type	Rating	No. of Shifts	No. of Days per Week	Personnel	Time Fraction and Other Duties	Special Costs
Naval Research Laboratory	Swimming pool	100 kw	1	5	Supervisor Facility Engineer Operators and Technicians Secretaries — 9 Cost	1 1 5 2 — 9 $63,000	Maintenance $37,000 Total $100,000
Penn. State Univ.	Swimming pool	100 kw	1	5	Director Deputy Director Electronics Technician Operators and Technicians Secretary — 7 Cost	1 1 1 3 1 — 7 $49,500 Total	Bldg. Maint. 2,000 Misc. Maint. 8,000 Replacement parts and supplies 10,000 Transportation 500 20,500 $70,000

TABLE III—*Continued*

Location	Type	Rating	No. of Shifts	No. of Days per Week	Personnel	Time Fraction and Other Duties	Special Costs
University of Michigan	Swimming pool	1 M.W.	1	5	Supervisor	¼ (teaching)	Operation Reactor Maint.
					Assoc. Supervisor	¼ (teaching)	$11,000 Bldg. Maint.
					Operator-Mech.	1	2,000 Shop Service
					Operator-Elect.	1	3,000 Administration
					Secretary	1	1,500 Construction
					Technicians	5	3,000
						2	
						7	
			Equivalent of Support from Phoenix Lab.		Cost	$45,000	20,500
		(Part of $145,000 Total Budget of Phoenix Laboratory)				Total	$65,500

TABLE IV

SPECIAL ON ARMOUR RESEARCH FOUNDATION

Location	Type	Rating	Date Planning Started	Extent of Planning by Home Staff	Remarks	Cost
Armour Res. Foundation (Chicago)	Water boiler	50 kw (Now at 10 kw) (Expect 100 kw)	Spring 1953	Preliminary and conceptual	Worked closely with N.A.A. during construction	$25,000 (2 man years equiv.)

Contract Coverage	Contractor	Dates		Cost
		Start	Completion	
General	A.R.F.	July 1955	June 1956	
Reactor	N.A.A.			$220,000
Shields and part of bldg. used for reactor and associated laboratories				
Triple containment				
Crane, tank and capital equipment	Local			
Associated labs.			Estimated Total	$650,000*

No. of Shifts	No. of Days per Week	Personnel		Special Costs
1	5	Reactor Supervisor	1	Fuel $1,100 (4% interest)
		Associate Supervisor	1	Insurance $3,000
		Operations Chief	1	Maintenance $50,000 over 3 yrs. max.
		Operator Tech.	3	
		From H.P. Staff	2	
		From Lab Staff	¼	
			8¼	
		Cost	$60,000	Total $80,000 Approx.

* (Out of $1.3 million for Total Physics and E. E. Res. Bldg.)

Design

The second step is design. The preparation of the design drawings may be done by a faculty-level group devoting full time to this problem, or it may be turned over to a design and consulting firm. This design is then used for construction. Another path is selection of one of the package units which have now become available and in which the design cost is absorbed.

In any case, there must be responsible senior staff time, which is often costly, spent on comparing these approaches.

Construction

Reactor construction should include all activity from the time ground breaking or equipment construction and procurement begins until the first critical experiment is completed. However, because of the nature of the projects to date, there has been much planning activity during actual construction. For this reason, university or laboratory personnel costs incurred during construction appear under planning (Table I).

In Table II, the information on construction costs is summarized. Where

a useful breakdown was available, this was duplicated. Here, the differences in approach and bookkeeping among groups again emerge. Some include site cost, others site improvement, others just skip it. The equipment installed as part of the reactor varies, although we tried to hold this variation to a minimum. Certainly, building requirements are quite different and influence total cost greatly.

One conclusion is easily arrived at, however. It would be dangerous to consider a reactor project, of the type discussed, including building costs with less than $500,000 as an initial fund.

Operation

The greatest variation appears to come in the operating budgets listed in Table III. However, these arise more from differences in the amount of time the reactor is in operation and the complexity of the installation rather than from differences in approach. Continuous, responsible supervision by persons hired for that purpose is essential to safety and reliability.

Another important difference is in the charges made against the reactor operation. Battelle must amortize the reactor, as well as pay running expenses. No other group shows this charge. Services such as electricity and water are absorbed by parent organizations in some cases but not all.

Here again, the reader must select those charges which represent a legitimate differential over present costs and which he will have to meet. In this regard, Pennsylvania State and Michigan appear to have the lowest cost to date; and these are by no means small.

The analysis of costs presented herein is not exhaustive. It is intended to be representative and, to this extent, useful to those contemplating new projects.

As a last word of caution on manufacturers' prices, the package for which Michigan paid about $200,000 (metal parts, cooling system instruments and controls) will cost today closer to $500,000. The Argonaut type, not covered in this article, has gone from less than $100,000 originally claimed when it was announced to about $180,000 to $200,000. Please treat all numbers in the tables as a guide and take careful note of all dates listed.

The foregoing contained no information on water boilers. Through special cooperation of the Armour Research Foundation, the data in Table IV were made available.

NUCLEAR REACTOR AT IOWA STATE

A contract to construct a nuclear reactor at Iowa State College, Ames, Iowa, for the teaching of nuclear engineering has been awarded to American-Standard Atomic Energy Division.

Construction will start as soon as remodeling of sections of the Iowa State West Chemical Engineering Building can be completed to accommodate the new laboratory tool, Frank A. Parker, Atomic Energy Division Director, said. Completion is expected in about 12 months. Funds have come largely from the United States Atomic Energy Commission. The reactor is of the "Argonaut" type.

A NATURAL URANIUM-GRAPHITE SUBCRITICAL REACTOR SYSTEM FOR EDUCATION AND RESEARCH—AN ABSTRACT

ALBERT L. BABB

Associate Professor, Department of Chemical Engineering
University of Washington, Seattle

Abstract of a paper presented at the ASEE Annual Meeting, June, 1958, Berkeley, California.

The first exponential experiment was conceived during the development of the first nuclear chain reacting pile in the West Stands Metallurgical Laboratory of the University of Chicago by Enrico Fermi and his coworkers. Since that time the exponential experiment has been widely used in the development of reactor concepts. By means of the exponential experiment it has been possible to measure accurately such lattice parameters of a heterogeneous system as material buckling, infinite multiplication constant, and thermal utilization, to mention a few. These quantities are essential in the determination of the conditions for criticality of a reactor, but very difficult to determine accurately from theoretical calculations alone. For example, the optimum lattice spacing for maximum conversion of U-238 to Pu-239 in the Hanford reactors was obtained by exponential experiments.

On the other hand, the exponential pile or subcritical assembly upon which the exponential experiments are performed is an excellent educational tool. It serves as a basis for introducing engineers to the problems associated with the nuclear chain reaction with a minimum of expense and very little hazard. In fact, almost all of the steady state reactor physics type experiments that can be performed on a critical pile can be performed on an exponential pile.

Many exponential measurements have been reported, and exponential piles moderated with both light and heavy water and fueled with both natural and enriched uranium have been described. Specifically, experiments on natural uranium-graphite moderated subcritical reactors have been performed at Hanford, at Oak Ridge National Laboratory, at Argonne National Laboratory, at Harwell, and at Brussels. Because of the current interest in gas and water cooled natural uranium-graphite reactors, and because of its utility as an educational tool, a natural uranium-graphite subcritical reactor was constructed at the University of Washington. While this facility is primarily for pedagogical purposes, it has been constructed so that useful technical data can also be obtained.

The reactor in one configuration consists of a 65 in. cube of reactor grade graphite weighing about 7 metric tons which rests on a $75 \times 75 \times 26\frac{1}{4}$ inch graphite pedestal weighing about 4 metric tons. In this arrangement 81 horizontal holes on $7\frac{11}{16}$ in. centers pierce the graphite lattice from front to back. Standard Hanford aluminum process tubes $1\frac{3}{4}$ in. outer diameter are inserted in the holes and 8 Hanford fuel elements clad in aluminum are inserted in each process tube. The aluminum process tubes are capped on both ends and interconnected through a manifold

so that the annulus between the fuel elements and the process tube may be filled with the liquids and compressed gases. A cadmium shutter may be inserted between the lattice and pedestal for certain measurements. The reactor is driven by 4 one-curie Pu-Be neutron sources arranged in a diamond array. The sources can be located in any one of three levels in the graphite pedestal.

Provisions have been made in the reactor for horizontal and vertical traverses using foils or neutron counters to determine lattice constants. In addition, a travelling monitor has been constructed so that accurate flux determinations may be made at 2 inch intervals when 10,000 counts have been detected by standard scaling and amplifying equipment used with a BF_3 neutron counter. By means of an analog-digital converter and an x-y recorder, the actual counting rate at each station in the reactor is plotted. This information is then transferred to punched cards preparatory to fitting the horizontal neutron flux data to a cosine function and the vertical flux data to an exponential function using a least squares technique programmed for an IBM 650 Computing Machine. The computations of end and harmonic corrections are also included in the program. Experiments performed in the instructional program are described and typical data are presented.

The measurements discussed in this paper are only a few of the total number of experimental measurements that may be made on an exponential pile. A more complete list includes: diffusion length, Fermi age, effective size, material buckling, thermal utilization, multiplication constant, neutron temperature, albedo, control rod perturbations, reflector savings for the graphite pedestal which has a larger geometric cross section than the lattice, temperature, coefficient, and coolant evaluation. The actual measurement of these quantities by students enables them to obtain a feel for reactor physics which is a requisite of a nuclear engineer.

1959 NUCLEAR CONGRESS CLEVELAND APRIL 5–10

Plans for the 1959 Nuclear Congress, to be held at the Cleveland Auditorium in Cleveland, April 5–10, have been announced by Engineers Joint Council. As in the past the Fifth Congress will be composed of four parts: the Nuclear Engineering and Science Conference, the Hot Laboratories and Equipment Conference, the Atomic Energy Management Conference, and the Atomfair, at which nuclear equipment will be on display. ASEE is one of the sponsoring organizations for this Congress.

Information on the Congress may be obtained from:

T. A. MARSHALL, JR. (Congress Manager) or
L. K. WHEELOCK (Assistant Manager)
c/o Engineers Joint Council
29 West 39th Street
New York 18, New York

Summary Report

NUCLEAR MANPOWER SURVEY IN UNIVERSITIES AND COLLEGES

LEE VANCE McLEAN, Project Director

Professor of Electrical Engineering
Louisiana State University, Baton Rouge

This is a summary of the findings reported at the 1958 ASEE Annual Meeting in Berkeley. A complete report of the results of the Survey has been published by the Atomic Energy Commission and is now available from the Office of Industrial Relations, U. S. Atomic Energy Commission, Washington 25, D. C. The title is "Scientific and Engineering Manpower Requirements for College and University Atomic Energy Activities."

The need for scientists and engineers for educational atomic energy activities will increase by 21 per cent by 1960–61.

There were about 4,700 scientists and engineers engaged in educational atomic energy activities at colleges and universities during the 1956–57 academic year. The number had increased to 5,420 for the 1957–58 academic year and should reach 5,680 by the 1960–61 academic year.

Of 182 schools reporting in the survey, nearly half (47 per cent) were privately administrated while 53 per cent were publicly administrated. In 1956–57, the publicly administrated schools employed approximately 67 per cent of the total personnel reported.

On an average, only 23 per cent of the scientific and engineering personnel working on educational atomic energy activities are working full time in this field, while 77 per cent devote only part time to educational atomic energy activities.

Approximately 86 per cent of the total personnel reported active in educational atomic energy activities are scientists, while only 14 per cent are engineers. There is relatively little change in these percentages as indicated by comparing 1956–57 with 1957–58, the percentage increasing to only 15 per cent in 1957–58. This change could be significant if it continues.

The largest group in the sciences in 1956–57 was chemistry and biochemistry, accounting for approximately 24 per cent of the total personnel reported. This group was only slightly larger than physics and biophysics, which account for approximately 22 per cent of the total personnel reported.

The largest engineering discipline in 1956–57 was chemical engineering, which accounted for approximately 27 per cent of the engineers reported, but only about four per cent of the total personnel reported. Mechanical engineering accounts for only slightly less engineering personnel than does chemical engineering, about 22 per cent.

The Shortage

There does appear to be a real shortage of scientists and engineers in educational atomic energy activities, but this over-all shortage does not appear to be critical at this time. Critical shortages of particular professions at individual schools do exist. The future demand could be greatly influenced by the development of the nuclear industry and their subsequent

TABLE 1

NUMBER OF SCHOOLS THAT NOW HAVE OR REPORTED THAT THEY SOON WILL HAVE ATOMIC ENERGY PROGRAMS*

	1956–57 Program	1957–58 Program	In the Future
Yes	38	20	29
No	47	22	
No response		5	18
Total	85	47	47

* Information requested only of those schools that did not have atomic energy programs in 1956–57.

need for personnel trained in these areas.

Approximately 43 per cent of the schools reporting indicated personnel shortages amounting to eight per cent of the total personnel employed by all respondents in educational atomic energy activities.

Most scientists and engineers engaged in educational atomic energy activities either work in "research and development only" or "combined teaching and research and development" and account for approximately 89 per cent of all personnel reported. Few persons, about 11 per cent, are limited in their activity to "teaching only."

The type activity currently requiring the largest number of personnel is in the biomedical field. Next in order are by-product applications and irradiation studies. The activities reported as "other" activities actually were in second place, indicating the relatively large number of educational personnel engaged in highly specialized activities that do not readily fall into the activity categories listed in the questionnaire.

Training

While most persons working as scientists and engineers in the educational atomic energy field have extensive training in some scientific or engineering discipline, most have acquired atomic energy training by actual experience. There appears to be a continuing need for specialized training for faculty and research staff of schools in the atomic energy field.

Approximately 55 per cent of the scientists and engineers engaged in educational atomic energy activities hold a doctorate.

About 30 per cent of all scientists and engineers reported have three or more years of atomic energy experience, while 66 per cent have more than three years of over-all professional experience in their specialty, much of it gained through AEC facilities.

Approximately 50 per cent of the total number of scientists and engineers engaged in educational atomic energy activities have had some type

TABLE 2

CURRENT SHORTAGES OF ACADEMIC AND RESEARCH STAFF

	Number of Employees Needed	Per Cent of Those Employed in 1956–57
Engineers		
Aeronautical	2	18.2
Ceramic		
Chemical	8	4.8
Civil	1	3.7
Electrical	13	13.4
Marine		
Mechanical	11	8.0
Metallurgical	6	9.1
Mining		
Nuclear	36	59.0
Other	17	35.4
Total	94	15.1
Scientists		
Biological and Agricultural	37	4.7
Chemist and Biochemist	60	5.7
Geologist and Geophysicist	1	1.7
Health Physicist and Ind. Hygienist	12	28.6
Mathematician and Statistician	7	38.9
Meteorologist		
Medical	14	2.0
Physicist and Biophysicist	61	6.3
Other	82	56.6
Total	274	7.2
Total Engineers and Scientists	368	8.3

Number of Schools Reporting Staff Shortages:

Yes	79
No	93
No Response to Question	15

TABLE 3

ESTIMATED MANPOWER EMPLOYMENT FOR 1956–57 AND 1957–58 AND PROJECTIONS TO 1960–61 BY "SCIENTIST" AND "ENGINEER" GROUPS

Year	Scientists		Engineers		Total
	Number	Per Cent of Total	Number	Per Cent of Total	
1956–57*	4038	86	658	14	4696
1957–58*	4455	85	783	15	5238
1960–61†	4833	85	846	15	5679
1960–61‡	4657	82	1022	18	5679

* Reported data adjusted for non-respondents and taken from Table 9A, Appendix A.
† Based on the proportion of engineers and scientists remaining constant at the 1957–58 level.
‡ Based on the indicated increase in the proportion of engineers and scientists shown by comparing 1956–57 with 1957–58.

of specialized training in atomic energy education. Atomic energy education has benefited by the active support given by the AEC.

Some 141 schools indicate a desire to have 1,146 personnel receive additional short course training in a variety of specialized subjects.

Some 144 schools reported they would like to assign personnel for one-year periods to gain on-the-job atomic energy training at AEC installations. The number of persons that were indicated as available for assignment by schools is 379 for 1958–59.

NUCLEAR ENGINEERING AT ILLINOIS

A new teaching program in nuclear engineering at the University of Illinois is moving ahead with grants of material from the Atomic Energy Commission.

The AEC has given the University's College of Engineering natural uranium rods, radioactive sources of plutonium with beryllium, and a large quantity of graphite. Still pending is a University request for funds to aid in the construction of a teaching reactor.

Faculty and students will construct two subcritical assemblies with the graphite and other material. The piles will be used to study nuclear reactions and the design and construction of reactors.

The Illinois nuclear engineering program, a curriculum for graduate students, is under the direction of Professors Marvin E. Wyman and Felix T. Adler. Wyman, an experimental physicist, has worked at the Los Alamos Scientific Laboratories. Adler, a theoretical physicist, has been with the General Atomic Division of General Dynamics Corporation and the Oak Ridge Atomic Laboratories as a consultant.

Now in its second year, the Illinois program is offering six courses including Nuclear Reactor Theory and Nuclear Engineering Laboratory Investigations.

THE ENGINEER AND THE ATOMIC INDUSTRY

WILLARD F. LIBBY

Commissioner United States Atomic Energy Commission

Presented before the National Capital Area Section, American Society for Engineering Education, Washington, D. C. February, 1957.

The new science and engineering of the atomic age derives from the increased importance of nuclear phenomena. Prior to December 1938 no large use of radioactivity or nuclear energy existed. The discovery by Hahn and Strassman and Meitner of nuclear fission changed this abruptly, however, and overnight the new engineering was conceived. It was born on December 2, 1942, four years later, when the first controlled release of nuclear energy was achieved by the late Enrico Fermi at Chicago. It had a rapid further development to a military fruition in July, 1945, when the first atomic bomb was demonstrated at Alamagordo.

Prior to these recent events the only common phenomena of nature which were essentially nuclear in nature were mass and sunlight, mass being principally nuclear and the sun's energy deriving from a fusion reaction. Thus we see there is a new science and engineering in the atomic age—the science and engineering of nuclear phenomena.

We must educate engineers and scientists for this new work in order that the development of the atomic uses, peaceful and military, may proceed. This must be a two-fold program—both for graduate engineers and scientists as well as for new undergraduates and graduate students. We must teach practicing graduate engineers and scientists the new points and also train the new undergraduate students in the new discipline. It is a large and difficult task, but progress is being made and we have reason to believe that atomic energy will fare well in this respect relative to other technical fields. The problem is that there are fewer engineers and scientists than the overwhelming demand requires. Atomic energy recruiting can compete with other technical fields, but it suffers seriously together with the others from the over-all shortage. The national atomic energy program benefits more from the addition of new technical men brought into the nuclear energy field by private industry than it does from the private financing of atomic power plants. Nothing can be done without these technical people and the supply is limited.

Toward a Solution

The steps necessary to solve this problem are not clear, but various facts appear to be important:

1. High school teachers are relatively poorly paid, so it is difficult to offer the scientific subjects for which the teachers can command much higher pay outside. At the present big city high school and college teachers receive real pay about equal to 1904, while the real wages of labor, in general, have doubled or trebled so that there is little monetary incentive left for people to become teachers.

2. Engineers and scientists are not as well paid as they might be. This is being corrected rapidly, however, by the law of supply and demand.

3. The technical life is a hard one—scientists and engineers must be interested and devoted to be competent—the desire to make money will never suffice alone.

Something subtle appears to be wrong in this vital regard. The technical life seems to be less attractive in this sense—so that other things being equal, law or business frequently win. Why? It may be that it is due to poor general explanation and description of the technical life. Let us see what it is that has not been said often enough.

1. The good things of life—in a material sense—all are derived at least in part from the efforts of technical people. Longer life, more survivals at birth and the rising standard of living are directly attributable to technical advances. Therefore, the engineer-scientist's life is a useful one.

2. The life being useful, it is also exciting. Nothing in human experience equals the discovery of a fact never before known to man. A bond never to be broken is formed thus, which has effects forever afterward. There is no doubt that people who have done this are happy in their work in the main and leave it only for the gravest reasons.

The thrill of discovery of permanent additions to human knowledge should be better imparted to high school teachers and students, so this great fact can play its proper role in the fateful early decisions about what the student intends to study and prepare himself to do in adult life.

3. A host of minor additional facts have not been adequately explained to the high school student—such as the fact that technical salaries are comfortable, though less than they might be; that many interesting people are known by all technical people—there is a certain fellowship which binds them together just as in the arts; that even for non-technical people a scientific education may well be worthwhile—when so much of our modern economy is coming to depend directly and in short-term on research.

The technological benefits of modern times largely follow from the understanding that basic science is practical and from the principle that invention in itself is not adequate. We have learned that system, that bodies of laws underlying the flights of human fantasy and intuition which lead to great discovery, are most essential and effective. The series of advances and discoveries in chemical science that has marked the last two generations is quite the most remarkable in the whole of history. It is difficult to understand the field's being unattractive to brilliant young people.

However, we must try to analyze what seems to be fact, and it appears that perhaps first in the causes for our difficulties are the rather unsatisfactory salaries which are paid men of real competence in the sciences. It is clear that there is no real way of repaying with money a research and development man who is really successful. How can you speak of rewarding Fermi for his contributions? Is there any possible way in which Carrothers (the discoverer of nylon) could have been compensated? How can one think that Faraday could have been adequately and fairly treated in a monetary manner? However, to the students who have to make their way and have debts to pay, the thought that the ceilings to their salaries are likely to be lower than if they chose some other profession is by no means insignificant. It is particularly important for the less gifted of the students contemplating scientific careers who realize that they will never be leaders in their field. They are discouraged from becoming helpers and co-workers because it is clear that the

leaders themselves are not well compensated.

Possibly the second most important factor involved in the decreased enrollment in the basic sciences is the quality and quantity of instruction in the secondary schools—more the quantity than the quality. The teachers now teaching sciences in the high schools probably are doing as good a job as their predecessors did but there are relatively fewer of them.

Lawyers and doctors have for many years been accustomed to assisting in instruction in their specialties in the colleges of the country. The bases for such part-time teaching have been well set in practice and seem to be generally acceptable. It seems possible, therefore, that school principals and boards of education faced with the problem of offering the essential sciences in their curricula might invite resident scientists and engineers in their communities to assist in the technical instruction on a part-time basis. Arrangements could be made so the problems of integration of the student's education could be handled and questions of counselling and discipline would not be neglected. Certainly such arrangements could fill a temporary shortage and might be found to be a more or less permanent solution, for it does not seem likely that high school teachers' salaries are likely to become in any way competitive with those elsewhere available to trained scientists and engineers. Of course, it might be said that it is not necessary that science be taught by trained scientists or engineers. In view, however, of the great importance of sound understanding of the subject matter to the protection and fostering of interest in the able students, it appears to be desirable that direct contact with practicing technical people might help reverse the present discouraging trends.

Perhaps a third factor is the quality of instruction in the colleges and universities in the basic sciences. The beginning courses in physics and chemistry are an opportunity to enlist students in the fields. It is of extreme importance that these courses be well taught, that the subject be presented in an interesting and understandable way, not in any way ignoring the basic difficulties, but not with such a mass of detail that the beauty of the basic principles is obscured. It is vital that the better teachers in the whole of the university faculties be asked to teach the beginning courses. It is essential that the laboratory experiments used in the instruction be wisely chosen and well equipped so that the ordinary difficulties of experimentation may not mask the attractiveness of the subjects. It is also important that the teacher of the beginning course in physics or chemistry seriously consider his counselling responsibilities so that students who are interested in the sciences will be encouraged, and that the students who are having difficulties of a temporary character will be led to persevere. He should see that the brilliant students pursue the subject matter beyond the general level of the class so that boredom and frustration will not divert them into other fields. The freshman science teacher is certainly one of the vital cogs in the machinery which trains and ensures the supply of basic scientists. It is clear at the present time that this job is not being done perfectly and that this may be one of the principal factors which needs serious attention in remedying the shortage.

A.E.C. Programs

The Atomic Energy Commission has taken certain steps to alleviate the situation, and I would like to describe them briefly to you.

The new and expanded programs are designed:

(a) *For the immediate future,* to expand specialized training in nuclear energy technology for industrial and Government employees and a quota of foreign nationals; and

(b) *For the longer range:*

(1) To assist colleges and universities in establishing curricula and acquiring scientific equipment for use in nuclear science and engineering instruction; and

(2) To interest high school students and teachers in nuclear subjects.

In addition, the Commission is conducting a series of surveys in an attempt to:

(a) Pinpoint needs in the United States as well as in connection with international commitments, over the next 20 years for individuals trained in nuclear science and engineering; and

(b) Determine whether or not the planned facilities of Commission installations, industry, colleges and universities, will meet the needs.

Meeting Current Manpower Needs

Graduate School Training. The Commission operates two special graduate schools, each providing one-year graduate programs in reactor technology:

(a) The Oak Ridge School of Reactor Technology (ORSORT) at the Oak Ridge National Laboratory is classified and is for students sponsored by American industries and Government Agencies. ORSORT has graduated 469 students since its establishment in 1950. Arrangements have been made with six colleges and universities for sponsored students to take the first half of the ORSORT course of instruction on college and university campuses. The second half will be at ORSORT. The first classes were held in February 1957. This plan makes it possible to double the number of students from approximately 120 to 240 per year.

(b) *The International School of Nuclear Science and Engineering* (ISNSE) at Argonne National Laboratory was established in 1955 primarily to fulfill commitments under the President's Atoms for Peace program, and accepts foreign nationals as well as students sponsored by American industries. Of the 162 graduates to date, 116 have been from 34 foreign countries and 46 from the United States. Pennsylvania State University and North Carolina State College, both of which have nuclear reactors, now participate in the program by providing the first semester of study, after which a second advanced semester is provided at Argonne. The cooperative plan enables Argonne to accept 120 students each year, as compared with 60 per year previously.

Puerto Rican Nuclear Center. In 1957 the Commission ventured into a new area—nuclear education and training in a foreign language. The University of Puerto Rico is legally a U. S. institution, and in all respects an institution of high academic standards in the American pattern. On the other hand, the Commonwealth of Puerto Rico is culturally, linguistically, and geographically Latin American, thus providing a unique focus for an educational facility for our American neighbors on the south, as a part of our obligation under the Atoms for Peace program.

The Oak Ridge Institute of Nuclear Studies (ORINS), an association of 35 southern colleges under Commission contract, provides experimental medical and radiological residencies and training in the safe and efficient use of radioisotopes. Since its formation in 1948, ORINS has instructed

about 2,800 scientists from every State in the country, from Puerto Rico, Hawaii, and the District of Columbia, and from 44 other countries. Four-week courses in basic techniques are offered approximately 6 times each year. Two-week courses in veterinary radiological health are conducted primarily for Armed Forces veterinary personnel. Under its medical research program, ORINS offers one-year post-residencies in radiology and experimental medicine and three summer residencies for medical school staff.

On the Job Training. University people and industrial employees are gaining special experience through temporary work at a number of Commission installations. Such arrangements benefit the Commission programs by bringing into them some specialized talents not otherwise available. The individuals concerned also have opportunities for training.

(a) *Student Thesis Research.* At the Commission's laboratories, opportunities exist for outstanding students to do research which becomes the basis for master's and doctor's degrees. Applications are made by universities and colleges for students who have completed formal courses in chemistry, biology, mathematics, and other sciences. Consideration is being given to the expansion of this program to include students majoring in nuclear energy technology.

(b) *Practice Schools.* The Massachusetts Institute of Technology has assigned graduate students for on-the-job participation at Oak Ridge. Current plant problems are submitted for solution by the students under an MIT resident staff. Two or more students are assigned to a problem, and a Commission plant consultant assists them. Ordinarily, each problem lasts two weeks, and a student in one semester would be assigned eight or nine different problems and thus acquire actual engineering experience. This program is proving to be advantageous to both the AEC and to the students participating, and consideration is being given to expansion of the program to establish additional practice schools at other sites with other universities.

(c) *Summer Employment.* Commission facilities have increased their summer employment of graduate and undergraduate students, and of faculty members. Faculty members have participated in research programs at AEC laboratories during the summer months as well as during the regular academic year on leaves of absence from their colleges and universities. Last summer approximately 285 college faculty members were employed at Commission facilities. This program has been of great assistance to the AEC and is being continued and expanded.

(d) *Industrial Participation.* Industry personnel have been participating in increasing numbers in programs of Commission contractors. The period of participation averages approximately one year.

Fellowship Programs. Fellowships are offered by the Commission in radiological physics, industrial hygiene, industrial medicine, and nuclear energy technology.

(a) Fellowships in *radiological physics,* covering health problems associated with handling radioactive material and with the release of nuclear energy, provide for 9 months of formal graduate work at one of 4 universities, followed by 3 months of specialized study work at an AEC laboratory. In carrying through this program, Vanderbilt University cooperates with the Oak Ridge National Laboratory, the University of Rochester with the Brookhaven National Laboratory, and the University of Washington and the University of

Kansas with the Hanford Engineering works.

(b) Fellowships in *industrial hygiene* permit graduate study at Harvard University's school of Public Health or at the University of Pittsburgh's Graduate School of Public Health.

(c) Fellowships in *industrial medicine* provide advanced training at Harvard, Pittsburgh, Cincinnati, and Rochester Universities. After one year of academic training, the fellow may take another year of in-plant work at a major Commission facility.

(d) Recently a proposal was approved for AEC special fellowships in *nuclear energy technology*. This program provides for 150 graduate fellowships each year, with annual stipends, incidental institutional fees, and dependency allowances.

Assisting Educational Institutions

Faculty Training. A major problem of colleges and universities in conducting atomic energy curricula is a shortage of faculty with experience in nuclear energy fields. Last summer two institutes of two months each were conducted, one at Argonne National Laboratory and one at Brookhaven National Laboratory. This program was undertaken by the Commission in cooperation with the American Society for Engineering Education and the National Science Foundation, and provided material for engineering faculty members to use in teaching nuclear energy technology. Summer projects of this type have made substantial contributions to the AEC's program and represent an excellent method of making evaluation studies. The experience gained by the participants has assisted faculty members in presentation of scientific courses.

Provision of Materials, Facilities, Equipment and Services

(a) *Exponential Assemblies.* Exponential assemblies are excellent training devices for students in nuclear energy technology. Many experiments of a basic and fundamental nature may be conducted with them. Accordingly, the Commission assists non-profit educational institutions to acquire exponential assemblies for use in education and training activities. To date, natural uranium metal and neutron sources for exponential assemblies have been furnished to Virginia Polytechnic Institute, New York University, and the University of Florida. In addition, requests for exponential assemblies have been approved for Alabama Polytechnic Institute, City College of New York, Cornell University, Georgia Institute of Technology, University of Maryland, Yale University, Reed College, Massachusetts Institute of Technology, Iowa State College, Stanford University, North Carolina State College, Ohio State University, and Rensselaer Polytechnic Institute.

(b) *Research Reactors.* The Commission has furnished fuel elements, or solutions, for research reactors to a number of colleges and universities, has made specific offers of similar assistance to others and is studying additional projects of this type for still other educational institutions.

(c) *Educational Reactors.* The Argonne National Laboratory has developed a low power, thermal reactor of wide flexibility, with special safety features which make it particularly suitable for campus use in teaching courses in reactor theory and nuclear physics and in engineering laboratory experiments. The Commission is planning to provide assistance to educational institutions in the construction of such reactors.

(d) *Nuclear Materials.* The AEC has a policy for providing assistance to educational institutions in obtaining certain nuclear and other materials provided that they are used primarily for education and training in nuclear energy technology rather than for other purposes, such as research. The AEC will consider the loan of source, special nuclear, and by-product materials, as well as certain other materials such as graphite, heavy water, zirconium, hafnium, rare earths, neutron sources, and other materials peculiar to nuclear energy technology.

(e) *The "Oracle" Application Program.* Conducted by the University Relations Division, ORINS, and the Mathematics Panel of Oak Ridge National Laboratory, the program is designed to make available to universities throughout the Southern region the services of the high-speed digital computer, Oak Ridge Automatic Computer and Logical Engine (ORACLE). University personnel have not only computer time, but also the combined experience and knowledge of members of the Mathematics Panel to assist with computational problems arising in research activities.

(f) *Equipment and Teaching Aids.* The AEC makes grants and contributions to help non-profit educational institutions acquire teaching aids, demonstration apparatus, and laboratory equipment to be used primarily for educational and training purposes in nuclear energy technology courses rather than for research. This policy was announced on September 5, 1956. Inadequate proposals were submitted by a number of schools and even adequate proposals contained a number of deficiencies. Generally, the deficiencies are that the universities do not justify explicitly the need for many items of equipment they propose to procure under this program.

Grants now under consideration will mark the beginning of a real cooperative effort on the part of American universities, in general, and the Government to meet the need of more and better trained engineers and scientists—engineers and scientists who will contribute to the growing nuclear energy industry.

Dissemination of Scientific and Technical Information

(a) *Conferences, Seminars, Symposia, etc.* Conferences, seminars, short courses, and discussion groups are excellent media for the dissemination of new information, techniques, and ideas on a large variety of special subjects related to nuclear energy technology. Scientists from Commission facilities have lectured, organized, sponsored, and conducted seminars, taken part in colloquia, and carried on related activities at universities when there are expressed demands and demonstrated needs. These activities will be expanded and conducted initially at AEC laboratories, but AEC also seeks the cooperation of colleges and universities in organizing and conducting such programs on their campuses.

(b) *Literature.* Textbooks, laboratory manuals, and library reference materials must be prepared and disseminated in order to have effective educational and training programs. Revised classification policies, accelerated declassification programs, and revised guides to unclassified fields of research will ensure maximum availability of scientific and technical information consistent with national security interests. Simultaneously, expanded programs are being initiated for the preparation, publication, and dissemination of scientific and technical information covering government sponsored research and development in the atomic energy field. The Commission has added 17 new depository libraries to bring to 66 the number of official reference centers

housing complete collections of nonclassified reports. Most of these libraries are at colleges and universities, and the location of the depositories is such as to make at least one collection of unclassified documents available in each metropolitan center of 500,000 or more. In addition, a complete reference center on Government-developed information on atomic energy is established in the AEC's Technical Information Service at Oak Ridge, Tennessee.

Research Contracts. Through Commission support of research in the physical and biological sciences at colleges, universities, and other nonprofit institutions, more than 2,000 students annually receive assistance and training. The schools gain in experience for faculty and often acquire additional facilities for postgraduate programs.

College Conferences. A conference was held in September, 1956, at Gatlinburg, Tennessee, at which Commission personnel discussed with deans of colleges of engineering and with university and college presidents the need for scientists and engineers and the Commission's programs of assistance. A total of 293 representatives from 151 schools attended. Similar conferences will be planned in the future, as deemed appropriate.

High School Programs

Nuclear Energy Training for High School Science Teachers. In an effort to stimulate interest at the high school level in scientific careers in atomic energy, the Commission and the National Science Foundation jointly sponsored radiobiology training courses in 1956 at Duke University, Harvard University and the University of New Mexico, in which 59 high school science teachers participated. In addition, ORINS held two training courses for 96 high school teachers. In connection with the course, the AEC gave to each participant a radioisotope demonstration kit to be used in his home high school for instructional purposes. Because of the initial success of the program, it is planned to expand the work to 6 universities next year.

Summer Institutes. Under joint sponsorship of the AEC and the National Science Foundation, the second annual one-month Summer Institute in Secondary School Science Teaching was completed on July 6, 1956, and the first Summer Institute in College Science Teaching was conducted from July 9 to August 3, 1956. Each of these Summer Institutes was held at the Oak Ridge Institute of Nuclear Studies and was attended by 48 teachers. These institutes, which enlisted the services of outstanding scientists as lecturers, are designed to give a selected group of teachers in the physical sciences an up-to-date review of scientific developments, to stimulate interest, and to increase subject matter competence. The ultimate purpose is to help teachers interest a greater number of qualified students in scientific courses.

Exhibits. Five small mobile units, designed for ease of presentation in rural and small urban areas, are now in circulation. Four of these units, sponsored by the National University Extension Association, an organization comprising the Extension Divisions of 76 colleges and universities, and the United States Junior Chamber of Commerce, were scheduled for showing in 11 states. The fifth unit will be scheduled directly from Washington Headquarters of the AEC. The sponsoring organizations are making advance arrangements to assure widest possible participation of junior and senior high school students during the showings. Students and teachers will be urged to follow up their viewing of the exhibit by devoting

further classroom attention to the subject of atomic energy.

Traveling Science Demonstration Lecture Program. Under this program, administered by ORINS under the joint sponsorship of the AEC and the National Science Foundation, seven high school science teachers started in September, 1956, on visits to more than 200 high schools in 48 states and the District of Columbia. The program was designed to stimulate interest among high school students in science and science-teaching careers. Each teacher spent a week in each selected high school in his assigned area, giving lecture demonstrations before science classes and consulting with faculty members on science-teaching techniques. The teachers were traveling in station wagons equipped with more than 800 pounds of demonstration equipment. At the conclusion of the school year, the teachers returned to Oak Ridge to help evaluate the program.

Information Kits. There has been considerable acceleration in the number of requests received by the Commission for kits of published materials which are provided to high school students and teachers to show the opportunities and information available in the atomic energy field. In fiscal year 1955, nearly 5,800 kits were distributed; in fiscal year 1956, the Commission distributed about 8,000 kits; currently, the kits are being requested and distributed at nearly double the rate of last year. The standard kits contain general information on use of atomic energy in agriculture, medicine, power and other industry, basic scientific background, and such material, useful in school science projects, as instructions on building a low-cost Geiger counter. Special kits are also prepared on the request of teachers or pupils working on science fair or similar projects. Photographs and charts are lent for exhibition or instruction purposes.

Special Assistance. During the past fiscal year special assistance to elementary and secondary educational institutions included 297 talks to high school audiences and over 7,000 screenings of films on atomic energy.

The problem of scientific manpower and education is serious to all of our people and one which requires solution in the national interest. I believe that the problem is not insoluble. If everyone does his bit, we will solve it and proceed on our course of amassing rapid technical development with all of the material benefits to our people in the world as a whole that these entail.

NUCLEAR ENERGY EDUCATION NEWSLETTER

The *Newsletter* will again be published approximately once each month. It is the objective of the *Newsletter* to report briefly on activities and developments in nuclear energy education. Individuals and institutions are invited to submit topics for inclusion. To the extent that space is available and the material appropriate, it will be included. All such material should be forwarded to the Office of the Secretary, ASEE.

THE IMPACT OF NUCLEAR PHYSICS ON AGRICULTURAL ENGINEERING

JOHN E. NICHOLAS

Professor Emeritus of Agricultural Engineering
The Pennsylvania State University

Presented at the April, 1957, meeting of the Allegheny Section of ASEE.

The principal function of agriculture is the production of food for man. The food that he eats comes either directly or indirectly from plants. Much of his clothing also comes from them, and plant products are used to a considerable extent for human and animal shelter and for manifold other purposes. Anything, therefore, that interferes seriously with man's attempt to grow crops interferes with the existence of the human race.

Among the greatest hazards in the production of plants are unfavorable weather, plagues of insect pests, and epidemics of plant disease. Anyone of the three can upset the calculations of crop production with catastrophic suddenness.

A number of years ago I pointed out in a paper published in *Agricultural Engineering* that:

I. Electronic radiation provides a promising means of reducing losses in agriculture from insects and disease.

II. Ultraviolet rays may be used (a) to destroy micro-organisms, (b) to produce vitamin D, and (c) to sort or select agricultural products.

III. Infrared rays may be used (a) for dehydration of grains and forages, (b) for sexual stimulation of fowls (perhaps other animals), and (c) for therapy and general heating.

IV. High frequency radiation may be used (a) to destroy disease and other objectionable organisms, (b) to create artificial fevers (therapeutic agent), (c) to kill insects and other small animals, (d) to improve germination of seeds.

It is now quite evident that the developments forecast are possible. I am of the opinion, however, that the impact of modern nuclear engineering on agricultural engineering has not yet been recognized. The inclination of agricultural engineers is to view such developments as nuclear fission as "basic" science or "pure" physics research. They almost completely ignore this new knowledge without attempting to understand fully or study deeply the principles which have made such a release of power possible.

I fear that they are going to be "very slow" in accepting the profound contributions to science made in recent years by physicists.

A Challenge

The controlled release of nuclear energy was a stupendous accomplishment. A great deal of work has already been done by physicists and nuclear engineers in directing atomic energy to industrial applications. To increase the store of knowledge on the need and effectiveness of atomic energy in the ramified field of agriculture and its related industry should be a challenge to the modern agricultural engineer.

Radiation, per se, as now understood, covers considerable ground. It might be placed in these categories:

1. Solar or cosmic.
2. High energy electron.
   (a) Capacitron
   (b) Resonant transformer
   (c) Van de Graaff accelerator
   (d) Linear accelerator, etc.
3. Nuclear
   (a) Fission products
   (b) Neutron
   (c) Gamma
   (d) Radioactive isotopes, etc.
4. Biological
   (a) Living tissue
   (b) Seeds
   (c) Chemical fertilizers, etc.

Reasonable strides have been made in discovering the composition of solar or cosmic radiation and its effect on biological and physiological specimens.

Reactors

The Pennsylvania State University reactor is a marvelous research tool for the staff and graduate students. Since April 1956, the reactor has been in routine operation with power levels up to 100 kilowatts.

Characteristics of the reactor follow:

Type:	Thermal
Fuel:	Enriched uranium in aluminum alloy sandwiches
Initial power:	100 kilowatts
Thermal neutron flux:	10^{12} neutrons/sec.-cm.^{2}
Critical mass:	7 lb. U-235
Pool capacity:	80,000 gallons

In the Agricultural Experiment Station, departmental representatives have indicated possible radiation interests and problems as follows:

Animal Nutrition—sterilization of diets for long-term experiments.

Forestry—no definite problems, but reactor facilities undoubtedly will be used in the future.

Dairy Science—sterilization of milk, cheese and ice cream mixes; cheese ripening; effects of radiation on metabolism of spermatozoa; induction of mutations by irradiation of spermatozoa.

Agricultural Engineering—fundamental studies of the distribution and utilization of energy.

Horticulture—seed treatment; induction of mutations; surface sterilization of sera; vaccine production; effect of radiation on susceptibility of cells to viruses.

Agronomy—treatment of grains for insects and disease; inhibitions of potato sprouting; induction of mutations.

Botany—induction of mutations in pathogens.

Agricultural Biochemistry—effects of radiation on plant metabolism; interdepartmental co-operation.

Bacteriology—inactivation of organisms for vaccines; effect of radiation on the cell.

Some progress may be claimed in the study of the problems suggested. I have brief notes from a number of our workers which I will call to your attention:

Frank B. Thomas
Assistant Professor of Horticulture

"Present activity in nuclear applications to horticultural problems is limited to committee work and literature studies. If a radiatoin facility were available similar to the Van de Graaff I would like to

pursue studies on radiation effects in fruits and vegetables. Flavor, texture, aroma, and other changes should be examined. 'Sterilizing' as well as 'pasteurizing' doses offer considerable interests with fruit and vegetables."

Darrell E. Walker
Assistant Professor of Plant Breeding

"In plant breeding we are primarily interested in the mutagenic effects of various types of radiant energy. The plant breeder must have genetic variability as his raw material and has evidence that irradiation speeds up the occurrence of mutations much in excess of the natural rate. To give examples, increased yield of peanuts and improved resistance to disease of oats have been reported."

Stuart Patton
Assistant Professor of Dairy Science

"We have been engaged in studying flavor deterioration which results in milk as a result of exposing the milk to gamma radiations. We were severely handicapped in this work because milk, a perishable item, had to be sent thousands of miles for radiation treatment. The shipping proved to be inconvenient and expensive. Moreover, we could only send limited amounts of material and this constituted a very real handicap in identifying the trace amounts of flavor compounds that are produced. More recently we have been exposing samples of milk in our reactor on the campus, with a view towards employing a combination of gamma radiation and heat treatment as a means of extending the keeping quality of fluid milk. As you know, free neutrons are a problem in using our reactor and there is no question that a pure gamma source would be much handier to work with in this research."

Andrew A. Benson
Department of Agricultural & Biological Chemistry

"Classically, activation analysis involves activation of a sample followed by chemical separation and counting to determine initial composition. This involved radiochemical separations, not always convenient.

"We chromatograph our samples on filter paper strips, or two-dimensionally on square sheets, this separates the ions or compounds of interest to us from each other and the many impurities. Mr. Yurow's work involves separation of Cu, Ca, Si, Mn, Co, Mg, Na, K, V, Mo, and other biologically important cations on paper. They are then activated with slow neutrons and their activities determined by a recording scanner (G-M, tube). With this method it may be possible to extract apple leaves, chromatograph the extract, activate the chromatogram, count the Cu, As, etc. areas to determine spray residues on the leaves. Eventually, it may be possible to measure biochemically important metalloproteins.

"We also are activating metabolic intermediate phosphate compounds which are separated on paper by chromatographic development with appropriate solvents. P^{32} formed in the neutron flux is detected with X-ray film and measured with large end windowed G-M tubes. With this method, it will not be necessary to disturb a biological system to incorporate a tracer but to detect the products and to measure their concentrations from the induced P^{32} activity."

C. E. French
Professor of Animal Nutrition

"In the field of nutrition research radioactive isotopes have been used widely to study the biochemical and physiological changes involved in digestion, absorption, metabolism and utilization of many nutrients. Irradiation sterilization of foods and experimental diets is a recent development of importance."

Robert J. Flipse
Associate Professor of Dairy Science

"I am interested in isotopes and ionizing radiation primarily as tools to be used in tracing metabolic and physiological processes in spermatozoa. To a lesser extent we are interested in the effects which different types of radiation have upon the metabolism of these cells, and in methods of modifying or preventing these effects."

In view of the diversity of interests, it was apparent that a single facility cannot meet all the radiation requirements for specific applied agricultural experiments and fundamental scientific investigations.

Because of the interest and diversity of application in intensity, magnitude and time interval, biological materials have been sent from our Experiment Station for radiation to Oak Ridge National Laboratory, Oak Ridge, Tennessee; Argonne National Laboratory, Lemont, Illinois; Materials Testing Reactor Station, Idaho Falls, Idaho, and other collaborating organizations.

While it is not yet clear which type of radiation offers the greatest possibility for experimental use for foods, seed, animals, or biological specimens, it is to be expected that facilities which provide controlled accelerated particles will play an equally important role with fissionable radiation.

Known Agricultural Uses for Radiation May Be Enumerated

1. Tracer studies in plants.
2. Bush beans—germination rate, sex ratio and mutation.
3. Rate of bone calcification—effect of Vitamin D.
4. Development of new plant varieties—breeding.
5. Absorption in animals and distribution in chickens of carbon 14.
6. Metabolism in sheep by cobalt carbonate and cobalt sulfate.
7. Radiobiological study of enzymes.
8. Phosphate tracer in production of fertilizer.
9. Placement and uptake studies of fertilizer in plants and plant leaves.
10. Effects of radiation on foods and on spoilage organism.
11. Effects of density of ions in air, and animals.

Use of Radioisotopes in Metabolic Studies Include

adipic and citric acids on animals
amino acid by microorganisms
antibiotics
antimony oxide
carbohydrate
carbon-14 in animals
cobalt carbonate and cobalt sulfate in sheep
copper carbonate and copper sulfate in cattle
dithymol diiodide in cattle
glucose by bacteria
iron and manganese as dietary mineral supplements
isonicotinic acid and hydrozide in animals
labeled compounds in animals
labeled drugs in animals
molds in relation to penicillin production
monochloracetic acid
nerve tissue
potassium iodide, iodinated protein and iodinated fats in rats
riboflavin
sodium phosphate, iron phosphate ferrum reductum and iron sulfate in cattle
steroids
sulfur dioxide treated silage
virus infected tissues
vitamin B_{12}
yeasts
zinc chloride and zinc carbonate in cattle

Utilization of Radioisotopes

A survey compiled by the Atomic Industrial Forum from records maintained by the Isotopes Extension of the Division of Civilian Application, United States Atomic Energy Commission from August 2, 1946, to February 9, 1956, shows:

1. Over 100 radioisotopes in use
2. In a total of 1347 installations
3. In 43 states, Hawaii and the District of Columbia.

If agricultural engineering, which cuts across all phases of food production, is to serve adequately and constructively, agricultural engineers must recognize and accept the impact of nuclear physics on their profession. Attention to suitable courses must be given in any planning of a curriculum in the future.

MOST POWERFUL EDUCATIONAL REACTOR

The Ford Nuclear Reactor at The University of Michigan is now operated at 1,000,000 watts, a ten-fold increase over the power level at which it has functioned since it was put into use September 19, 1957.

It is now the most powerful reactor at any of the nation's educational institutions. Authorization came from the Atomic Energy Commission after a lengthy series of reactor and control system calibrations. The increase will permit a much more diverse program of experiments and research.

The reactor is one of the most important physical parts of the University's Michigan Memorial-Phoenix Project, a unique campus-wide research activity devoted to finding peacetime uses of nuclear energy.

The general purpose of the reactor, which was made possible by a $1,000,000 grant from the Ford Motor Co. Fund, is to provide an intense source of neutron and gamma radiation for research, to supply radioactive isotopes, primarily those with short half-lives, and to aid in training scientists and engineers in reactor technology.

To permit versatile utilization of the reactor, three special experimental facilities have been built into the reactor installation. These are the beam ports, the thermal column and a pneumatic tube irradiation system.

The beam ports are horizontal aluminum tubes which penetrate the concrete shield at the base of the reactor installation and which allow beams of neutrons to be taken outside the shield. They also provide space where experiments may be performed which require service or instrument connections while the experiment is being irradiated. Additionally, samples which cannot be irradiated in the water around the core may be accommodated in any of these beam holes.

The thermal column is designed for dry irradiations requiring a large number of slow speed neutrons over a large volume. The column is a six by six by eight foot stack containing twelve and one-half tons of graphite, the graphite serving to moderate or slow down the fast neutrons from the core.

Samples up to four ounces in weight can be sent through the pneumatic tube system, exposed to irradiation at the core for as little as two seconds, and then returned to the fingertips of a chemist in a laboratory. The system has permitted considerable advances in chemical activation analyses in which extremely minute amounts —sometimes two-tenths of a part per billion—of an element can be detected and measured in a sample.

TOWARDS UNITY

(Ed. Note) This article appeared originally in the October, 1958 issue of the *Journal of the Engineers Guild*, the publication of the Engineers' Guild Ltd. of England, which has courteously given permission for reprinting the article here.

Aspiration and fulfilment are as oft in conflict as in accord. When in conflict, the failure of wishes and intentions to fructify in practical measures may be due to ineffectual resources or to unpropitious circumstances. Accord, by contrast, may come through pressure of favourable circumstances despite any slender resources of those who seek it.

Through the Engineers' Guild, professional engineers have for many years been proclaiming the need to bring unity to a badly disintegrated profession. Historical causes of the fragmentation have been widely recognised, disadvantages have been emphasised, and remedies have been discussed and recommended. Yet, until recently, very little happened in practice to alter the established pattern. Vested interest, inertia, doubt—all these held back the formulation of any single acceptable attitude of mind. The end remained remote because of inadequate means. And outside the engineering profession no one seemed to care anyway.

But now external circumstances are becoming favourable for re-establishing unity in the profession. The technical requirements for harnessing, controlling and exploiting the energy obtainable from nuclear fission, and fusion, are such as to encourage the closest collaboration between engineers from many fields of knowledge; engineers, moreover, who formerly worked with little or no contact with each other. Nuclear engineering is itself a specialised field of very recent growth, but the translation of theoretical nuclear physics into engineering designs and construction methods has drawn to it engineers from a variety of fields who are inspired to apply their conventional knowledge to this new source of power.

The United Kingdom Atomic Energy Authority pioneered the way, and, thanks to its foresight, help and encouragement, several industrial consortia are now well established for the design and construction of large nuclear power stations, and have in fact secured world leadership for Great Britain in practical nuclear engineering. Each consortium commands within its own resources all the engineering skills to cover design and construction of civil, mechanical, electrical and chemical works. Other great organisations in other spheres of activity do, of course, command similar resources, but probably never before have so many engineers of different skills been focused so closely upon a particular project.

All these new developments are essentially technical and commercial in basic purpose. But they have an incidental influence of profound importance for the engineering profession. Instead of the former segregation of skills, we now have a coming together, an intermingling which must surely create a much more favourable climate of opinion for eventually achieving unity within the profession. The working relationships now being developed amongst so many engineers of varied disciplines must surely engender a greater desire for corporate unity than ever before.

Similar evidence comes from the professional engineering institutions. To their credit, the engineering institutions were quick to foresee the need for close collaboration in nuclear en-

gineering, and in 1955 four of them, together with the Institute of Physics, founded the British Nuclear Energy Conference. Membership has since been extended to other institutions covering cognate technologies, the total number being now nine. The B.N.E.C. fulfils an invaluable function in the advancement of knowledge, and because it encourages an intermingling of engineers of diverse skills, it too contributes greatly to this very desirable recognition that all are in one great profession.

ASEE QUESTIONNAIRE PROCEDURE

During the past two years the Society has been severely criticized on a number of occasions for the large number of questionnaires which it has circulated, the poor quality of some of them, and the unreasonably short time sometimes permitted for their completion and return. The latter criticism particularly pertains to the two months immediately preceding the annual meeting of the Society. As a consequence, the General Council of the Society approved the following procedure for the use of questionnaires at its meeting on June 16 and 20, 1958.

1. All questionnaires shall be prepared in order that they be specific and studied for ease of answer.
2. All questionnaires shall be checked for duplication by the American Council on Education.
3. All questionnaires shall be critically reviewed by a committee before submission.
4. The use of all questionnaires shall be cleared with the secretary of the Society.
5. No questionnaires shall be mailed after March 1 for replies and completion prior to the next following annual meeting.
6. This procedure will be published in the JOURNAL and mimeographed copies sent to all the appropriate officers of all divisions, sections and committees.

NUCLEAR ENGINEERING DEPARTMENT ESTABLISHED AT MICHIGAN

Addition of a Department of Nuclear Engineering to The University of Michigan College of Engineering, effective July 1, was approved by the Regents in mid-June. The department will centralize the authority and responsibility for instruction in this new field, although instruction will continue to be confined to the graduate field. Teaching at present is accomplished by borrowing faculty from other departments. Currently there are 111 students in the Nuclear Engineering program, with 74 seeking Master's degrees and 37 seeking Doctor of Philosophy degrees.

Chairman of the new department will be Prof. Henry J. Gomberg. His appointment will be a half-time one, since he will continue as assistant director of the Phoenix Project, also on a half-time basis.

CONSCIOUS RECRUITING ON AN INDIVIDUAL BASIS: THE KEY TO THE ENGINEERING FACULTY SHORTAGE

HAROLD A. FOECKE

Project Director, CDEF
Assistant Professor of Electrical Engineering, Notre Dame University, Notre Dame, Indiana

"Generally speaking, the interest in teaching has been generated by the student himself rather than by a conscious stimulation on the part of faculty or administration. I do not think that [my institution] is unique in this respect." With these words a dean of engineering recently described the activities at his institution relative to recruiting students for engineering teaching. Those few words speak volumes about the cause of the present shortage of engineering teachers. But if, as the dean suggests, his institution is not unique in its avoidance of any conscious recruiting, it is nevertheless not a universal pattern, as indicated by the dean of another institution. "We do bring to the attention of our outstanding students the many fine opportunities in the field of engineering education in several different ways, the most effective of which has been personal contact between an enthusiastic professor and the student." The key to providing engineering teachers in the numbers needed now and in the decade ahead lies in the *conscious* stimulation of outstanding students by faculty and administration in various ways, the most effective of which is unquestionably the individual approach.

Such are the conclusions to date of the ASEE Committee on the Development of Engineering Faculties (CDEF) which has, since its appointment in late 1956, been studying all aspects of the problems of recruiting, developing, and utilizing engineering faculties. Last year CDEF prepared a report, (1), part of which dealt with engineering faculty requirements in the decade ahead. Having assessed the needs, CDEF proposed to make a thorough one-year study of activities or programs on individual campuses directed toward any one or all of the three following areas: (1) interesting more of the outstanding engineering students in teaching as a career, (2) providing for the systematic development of these young teachers, and (3) utilizing limited engineering faculty resources more effectively. It was further proposed that a full-time project director be engaged to conduct the study. The Ford Foundation supported the proposed one-year project which began officially on September 1, 1958.

Last July to launch the project, Dean Harold L. Hazen, Chairman of CDEF, sent a letter to all deans of engineering requesting simply a brief and informal indication of activities or programs at their respective institutions in any of the three aforementioned areas of Committee interest. The responses were to form the basis for follow-up correspondence and, in selected instances, a personal visit by the Project Director to obtain more detailed information on particularly promising programs. It was from these responses that the opening quo-

tations above were selected. Though it is greatly concerned with the problems of training and utilizing engineering teachers, CDEF turned its major attention during the first few months of the project to the area of recruiting. The purpose of this brief article is to indicate once again the magnitude of the task which should be our common concern and to suggest means of meeting the challenge implicit in the teacher shortage.

Recruiting season is upon us! Soon literally thousands of really outstanding engineering students will be making the important decision of whether to enter industry or to pursue resident graduate study. If they enter industry, even if they avail themselves of industry-sponsored graduate work, they are almost certainly shutting the door on a teaching career. If, on the other hand, they pursue resident graduate work and use those years to experiment with the possibility of a teaching career (through various forms of apprentice teaching), they have nothing to lose. If they discover they enjoy teaching and choose it as a career, they will be ever grateful for having given it a try and grateful too to those who encouraged them to do so. If they decide to pursue a career in industry, *both* the graduate work and the teaching experience will prove to be exceptionally valuable.

Shall engineering education lose forever the services of hundreds of these potentially outstanding teachers just because, in the language of the opening quotation, they failed during their undergraduate years to generate *by themselves* any interest in teaching? Engineering education can ill afford to depend for its supply of teachers upon the capricious laws of chance. The previously mentioned CDEF report (1) indicated that in the academic year 1956–7, out of a total of approximately 9,810 budgeted engineering faculty positions, 732 were simply unfilled. Another 532 equivalent full-time positions were being held by part-time, temporary, or unsatisfactory personnel. Therefore, out of a total of 9,810 positions, 1262 (about 13 per cent) were either completely vacant or unsatisfactorily filled. Evidently therefore, haphazard recruiting has not succeeded in supplying the demand in the recent past; for every seven to eight competent full-time teachers needed, one was missing in 1956–7.

With this handicap, engineering education entered a decade in which, if presently overburdened staffs are not to be completely swamped, new teachers must be recruited at an entirely unprecedented rate. If engineering education continues to avoid the *conscious* stimulation of its best students to consider engineering teaching as a career, it does so at its own peril. From the data in the CDEF report it is evident that by 1967 a total of about 16,000 engineering teachers will be needed. About 9,600 of these (60 per cent of the total) will have to be recruited between 1957 and 1967, partly to account for surging enrollments and partly to offset normal turnover due to retirement, death, loss to industry, etc. To recruit this large a body of teachers, conscious stimulation must be the order of the day.

The Personal Touch

To obtain an inventory of deliberate efforts to recruit engineering teachers, CDEF made a preliminary analysis of the responses of the deans to the letter of Dean Hazen last July. This resulted in a very brief report being sent to all deans of engineering highlighting those recruiting practices which, for one reason or another, seemed to merit wider publicity. The inescapable conclusion drawn from the analysis is that there simply is no substitute for the personal approach.

Talks at required senior seminars, presentations at student meetings, articles in engineering student publications, none of these, helpful as they are in their own way, are in the same league with the individual approach to an outstanding student by an enthusiastic teacher whom the student knows and respects. When a teacher who takes manifest delight in the academic life invites a serious-minded and perceptive student to enter the academic world and to share that life dedicated to teaching and learning, the psychological power of such an appeal would be hard to overestimate. Considering further that the alert teacher is privileged to spot some of the most promising students early in their undergraduate years and to sow then the seeds of the idea of teaching as a career, it would seem paradoxical that a shortage of teachers should ever exist at all.

In the hope of stimulating more such fruitful individual discussions between teachers and students, CDEF has prepared a brochure on engineering teaching as a career, which should be available for wide distribution in February. The brochure explicitly invites the student to discuss the subject more fully with one of his favorite teachers. It will have served its purpose if it does no more than that. Naturally no single brochure can be ideally suited for all its student readers; each student is apt to have a question or two which, in his opinion, were not dealt with satisfactorily. Similarly, the picture of the life of an engineering teacher which is painted by the brochure may not agree perfectly with each engineering teacher's view of his academic life. Therefore, the brochure can serve as a point of reference or departure for a discussion in which the student airs his questions and apprehensions and the teacher draws upon his experiences and insights to enlighten and enrich the discussion.

CDEF in the months ahead will be turning its attention to the problems of the systematic training and effective utilization of engineering faculties. In the meantime, it is to be hoped that each engineering teacher will grasp the seriousness of the situation and will respond by recruiting "in season and out of season," by seizing the natural opportunities which arise to exalt the teaching profession. By giving conscious thought to the selection and grooming of new teachers, the engineering teachers of today can insure for themselves a future in which faculty shortages are eliminated. By their individual eloquence they can enhance the stature of the engineering teaching profession by selectively inducting into its ranks recruits with life, vitality, and dynamism. On the other hand, by a collective conspiracy of silence engineering teachers can fail to selectively propagate their kind, can force students to "discover" teaching by themselves, thereby causing the supply of new teachers to depend upon random selection processes which would seem to foredoom engineering education, if not the very technical stature of this nation, to slow strangulation. *Conscious* recruiting on an *individual* basis, the key to the engineering faculty shortage, must be the order of the day!

Reference

1. William M. Miernyk and Morris A. Horowitz, "Engineering Enrollments and Faculty Requirements, 1957–1967," A Report of the ASEE Committee on the Development of Engineering Faculties, *Journal of Enginering Education*, Vol. 48, No. 9, pp. 789–859, May, 1958.

AN ANALYSIS OF "OTHER" ENGINEERING CURRICULA

HENRY H. ARMSBY

Chief for Engineering Education
U. S. Office of Education

Each year the U. S. Office of Education and the American Society for Engineering Education (ASEE) jointly sponsor the gathering, compilation, and publication of data on engineering enrollments and degrees granted. The sponsors publish separate reports, containing tabulations of a different form, which supplement each other, without duplication. Considerable interest has developed as to what curricula are included in the category "Other," which appears in each report. This article is written to give more detailed information concerning these curricula.

The two engineering enrollment and degree reports (U. S. Office of Education, Circular 516 and the JOURNAL February, 1958) classify students and degrees by 20 curricula plus "Unclassified" and "Other." The 20 curricula are those which are accredited in at least one institution by the Engineers' Council for Professional Development (ECPD). "Unclassified" students and degrees are those which the institution has not classified by curriculum while the "Other" designation is used for all remaining students and degrees.

The JOURNAL OF ENGINEERING EDUCATION report applies this classification to enrollments and degrees in institutions which have at least one curriculum accredited by ECPD. The Office of Education report (Circular 516) applies it to all institutions which grant engineering degrees.

Table I below is an analysis of the enrollments and degrees reported under "Other" in Circular 516. The distribution is in accordance with notations on the institutional reports. Added to the list in Table I are a few instances (indicated by the symbol #) in which the institutional report indicated that figures reported under one of the 20 listed curricula should have been reported under "Other." (These items are *not included* in the totals in Table I, which agree with those in Circular No. 516.)

Table II consists of an attempted further subdivision of the "Field Not Indicated" item in Table I. The first seven entries are enrollments and degrees which it is believed should have been entered under the accredited curriculum shown rather than under "Other." The last item, labeled "No Indication," represents enrollments and degrees which could not be identified.

It is, perhaps, significant that in the institutions having one or more curricula accredited by ECPD the percentage of enrollments and degrees which are reported as "Other" is much smaller than in the institutions not so accredited. In the ECPD-listed institutions, 1.1 per cent of all undergraduate enrollments are in the "Other" category. In the non-ECPD-listed institutions the percentage is 4.4. In the first group of institutions the percentage of bachelor's degrees reported as "Other" is 1.2, in the second group the percentage is 7.2. The non-ECPD-listed institutions reported only 1 per cent of the Nation's enrollment at the master's level, and no master's degrees granted. None of the master's enrollments were in the "Other" category. This group of institutic

TABLE I

ANALYSIS OF "OTHER" ENGINEERING CURRICULA LISTED ON ENGINEERING ENROLLMENT AND DEGREE REPORTS, FALL OF 1957

No. of Schools Reporting		Curriculum	Enrollments			Degrees		
Students	Degrees		BS	MS	PhD	BS	MS	PhD
1	2	Air Conditioning & Heating	99	—	—	36	—	—
1	1	Air Transportation	47	—	—	54	—	—
1	1	Bio-chemical	2	—	—	1	—	—
5	3	Building Construction	104	13	1	20	8	—
2	1	Design	61	—	—	10	—	—
1	1	Economics, Industrial	30	4	60	15	1	11
5	5	Electronics	1,092	54	—	221	5	—
8	6	Engineering Mathematics	327	43	28	43	9	5
11	7	Engineering Science*	*487	104	37	*29	15	2
1	1	Fire Protection	47	—	—	12	—	—
1	1	Fluid Dynamics & Hydraulics	—	13	8	—	3	—
1	1	Food Engineering	9	3	—	4	—	—
3	3	Fuel Technology* (incl. Gas Tech.)	*44	*6	*11	*12	*2	—
0	1	Furniture Mfg. & Mgt.	—	—	—	22	—	—
1	1	Glass Technology	—	2	—	—	2	—
1	0	Humanities & Engineering	30	—	—	—	—	—
2	2	Instrumentation (& Servomechanisms)	—	80	11	—	16	2
2	1	Irrigation	—	17	6	—	10	1
2	1	Law, Engineering	20	—	—	2	—	—
1	1	Leather Technology	22	1	—	1	—	—
1	0	Materials Engineering†	†13	†1	—	—	—	—
3	2	Meteorological Engineering	35	21	—	8	10	—
11	7	Nuclear Engineering	98	161	45	23	66	2
1	1	Nuclear Engineering†	†330	†37	†11	—	†1	—
2	2	Ordnance Eng'g (Includes Mine Warfare and Nuclear Weapons)	101	29	—	1	17	—
2	2	Paper & Pulp Engineering	62	12	—	18	4	—
0	1	Planning Engineering	—	—	—	2	1	—
2	1	Plastics Engineering	83	7	—	—	4	—
1	1	Process Engineering	7	1	—	5	—	—
1	2	Public Health Engineering	—	11	—	—	3	—
0	1	Tool Engineering	—	—	—	9	—	—
1	0	Tool Engineering†	†67	—	—	—	—	—
1	0	Transportation Engineering	—	16	7	—	—	—
1	1	Welding Engineering	35	4	—	3	1	—
1	0	Welding Engineering†	†7	—	—	—	—	—
14	10	Field Not Indicated* Table II	*458	*183	*12	*31	*39	6
		Totals (Omitting † items) (Totals agree with those in Circular 516)	4,110	785	226	582	213	29

* Partly estimated. One institution reported students and degrees for three curriculums combined. Estimated distribution among the three may be in error, but totals are not affected.

† Should have been reported under "Other," but actually reported under one of the 20 listed curriculums. *Not included* in totals.

TABLE II

PROBABLE DISTRIBUTION OF "FIELD NOT INDICATED" ITEM IN TABLE I

No. of Schools Reporting		Curriculum	Enrollments			Degrees		
Students	Degrees		BS	MS	PhD	BS	MS	PhD
1	2	Engineering Mechanics	—	9	—	—	5	5
5	1	General Engineering	112	57	—	18	—	—
1	0	Mining Engineers	31	—	—	—	—	—
1	0	Metallurgical Engineering	—	2	—	—	—	—
2	2	Mining or Metallurgical Eng'g	*35	*9	*12	*5	*4	—
0	1	Petroleum Engineering	—	—	—	2	—	—
1	—	Unclassified	275	—	—	—	—	—
11	6	Sub-totals	*453	*77	*12	*25	*9	5
3	4	No Indication	5	106	—	6	30	1
14	10	Totals	*458	*183	*12	*31	*39	6

* Partly estimated. One institution reported students and degrees for three curriculums combined. Estimated distribution among the three may be in error, but totals are not affected.

reported no enrollments and no degrees at the doctor's level.

This analysis of "Other" engineering curricula furnishes at least partial indication as to some of the changes which have been made in recent years in the types of engineering curricula offered in American colleges and universities. Many of them have been established fairly recently and reflect in some degree the response of the engineering colleges to such recent developments as the industrial and military uses of nuclear energy, electronic controls and computers, the rapidly expanding use of plastics, and the extension of automation. In some cases they also reflect the growing importance of inter-disciplinary studies (e.g., biochemistry, biophysics, etc.).

RENSSELAER COMPLETES EDUCATIONAL REACTOR

Rensselaer has completed construction of a subcritical uranium assembly, a type of atomic reactor which has been widely useful because it does not contain sufficient uranium to become explosive.

What is new about this subcritical reactor is its design. First of its kind, its instruments permit safe and easy measurement of changes in atomic phenomena brought about by changes in uranium arrangement, or by changes made in the materials used in the assembly. Thus, investigators are able to take a closer look at phenomena underlying atomic reactors.

The educational reactor was developed by R. P. I. faculty members with financial sponsorship by the Atomic Energy Commission. Total cost will be approximately $250,000 for the unit and associated research still underway.

FAMILY ENGINEERING OR THE NIGHT THE DOORS SLAMMED

JOHN A. HENRY

Professor of Mechanical Engineering
University of Illinois, Urbana

ASEE Annual Meetings have long been known for the large percentage of members who bring their families with them, and for the comprehensive programs planned by host institutions to make the Meetings enjoyable for these families. Here an ASEE member, aided and abetted, we are told, by his entire family, summarizes his experiences with ASEE's "Family Meetings."

The other night we finished pasting the summer pictures in the family scrapbook, and got to talking about vacations. We have been using the ASEE annual meetings for our recent vacation planning. It all started innocently enough. Five years ago, Alice (that's Mom) was drafted to help put on a children's program for the ASEE annual meeting at our home base at Illinois. Naturally, if she was baby-sitting, we were short of womanpower at home, so the two youngsters, Martha and Irene, came along with her. A little, very little, arm-twisting by another fine woman persuaded our teenagers, Dorothy and Don, that they should help to host the teenage group. Having invested several days in public service, the family thought it ought to catch the gravy train, so the battle cry became, "On to Penn State!" And on we came, to Penn State, Iowa State, Cornell and California. Our kids probably know more about the future schedules for these meetings than most members of ASEE.

For three of the trips we packed our camping gear in the utility trailer and camped before and after the conventions proper. This is not only cheaper, we happen to like it that way. While we prefer a little civilization at the meetings proper, we were impressed by the families who camped at Buttermilk Falls State Park on the outskirts of Ithaca. Last year at Yosemite, we ran into some convention friends from Penn State.

But let's get back to the conventions. Why have we enjoyed them? Everyone has a different idea. Alice says it's grand to have a few days when the kids are off her hands from nine till four. She can take tours, play cards, or just plain loaf—after she gets the camping clothes washed up. It's one of the few times the Old Man will take the family out for meals. When we have stayed in dormitories, she has enjoyed meeting old and new friends, and of course many of them are people who have left our campus for all parts of the country. And the experiences give us memories that help to hold the family together. Every once in a while someone brings up the night the doors slammed. There is no point in trying to explain it. It comes out about as funny as the story you try to tell about the dream of the night before—flat. But no one who spent that night in Balch Hall at Cornell will ever forget the bombardment.

Irene is the youngest. Nothing spectacular has happened to her yet, but she is the family collector. When she described herself as a trade rat, she was asked what she ever traded. "I always leave my fingerprints." She remembers the time that Old Baldy led the family on a safari for dinner one year. Despite the fact that he once had a course in surveying, he

managed to hold the map upside down or something, and everyone got an unscheduled campus tour on one of those famous hot evenings.

Mart is best remembered for the time she decided to visit the hill-top dormitories at Berkeley with one of her pals about five minutes before the evening roundup time. Four irritated parents and assorted kids found out once more that "tragedies" are the things one looks back on with the most enjoyment. The thing she prefers to remember is the time that she, Dorothy, and the old folks were on the Iowa State homemakers TV hour as a typical family enjoying a family convention program. Both of these girls relish the memory of dormitory meals alone while Mother and Dad go to one or another of the dinners.

Dorothy looks back at the time she got lost in Balch Hall, and that dreamy Jim (or was it Mike?) that she met at Ames. She is the family expert in key losing and pocketbook dropping. She says that the local committees should round up more local boys for the teenage affairs and have scads of records. She and Don, and indeed the old folks too, look back with real affection for Mrs. Veline at Iowa State, who went all out in this way and others to make the teen-agers happy.

Don has graduated from the teen-agers now, and will no more be seen prowling the halls, casing the feminine contingent. He loved the sociability, and often talks of and less often writes to some of the boys he met.

For the Parents

For the parents, there are some real compensations. We are proud of our colleagues, and proud to have our children associate with them on these annual occasions. It is good for them to learn that adults can have fun too, and that a convention can be a success without lavish entertainment and brawling in the halls. There are some unexpected occurrences. One does not know whether to smile or run when a perfect stranger looks at your badge and asks: "Are you the father of the boy my daughter walked home with last night?" Haven't had to run yet.

What experience can equal that of coming "home" from an affair and finding your two teen-agers there ahead of you? Twice in one week, no less. And then there was the time that Mother and Dad were approaching a social event at Penn State and spied a crowd gathered around the curb in front of the building. A familiar, almost masculine voice could be heard giving orders to the by-standers in approved Boy Scout fashion, clearing the area and sending his elders to the phone for help for a woman who had collapsed. Very confusing. Was this the young fellow who at home couldn't be depended on to pick up his clothes or be on time for meals?

There is not time to bring up the memories of Cape Cod, of State and National Parks and other by-products of our jaunts. Drop in some time and see our scrap books. We can't be sure we will be at Pittsburgh, Lafayette, Lexington and Colorado Springs. We'd like to be there, and hope to meet members of your family too.

TAU BETA PI 1959 CONVENTION

The 1959 national convention of Tau Beta Pi, national engineering honor society, will be held in October at Purdue University.

NOMINEES FOR ASEE OFFICES, 1959-60

For President, One Year

Benjamin R. Teare, Jr., Dean of the College of Engineering and Science, Carnegie Institute of Technology, has been a member of ASEE since 1933. In 1947 he received the George Westinghouse Award in recognition of his contributions to the improvement of methods for teaching engineering. He served as vice president for ASEE 1953–55.

Dean Teare received his B.S. from the University of Wisconsin in 1927 and his M.S. there in 1928. He received the Doctor of Engineering degree from Yale in 1937. In 1929 he was a test engineer for General Electric. In 1933 he became an instructor in electrical engineering at Yale and moved up to an assistant professorship in 1934. He went to Carnegie Tech as a full professor in 1939, became head of the electrical engineering department in 1944, Dean of Graduate Studies in 1950, Associate Dean of Engineering and Science in 1952, and Dean of Engineering and Science in 1953.

For Vice President, General and Regional Activities East of the Mississippi River, Two Years

R. G. Owens, Dean of Engineering at the Illinois Institute of Technology, has been a member of ASEE since 1944 and served as a member of the General Council 1956–58.

Dean Owens received his B.E.E. from Ohio State University in 1927, his M.S. there in 1928, and his Ph.D. from the University of Michigan in 1939. He was an instructor in physics at the University of West Virginia 1928–30 and at Western Reserve University 1930–37. He was special instructor in physics at Wayne University 1938–41, assistant professor of mechanics at Colorado School of Mines 1941–43, and associate professor there in 1943. He was supervisor of thermodynamics for the Armour Research Foundation 1943–46, professor of mechanical engineering at the Illinois Institute of Technology 1946–51, assistant dean of engineering 1951–52, and has been Dean of Engineering since 1952.

For Vice President, General Divisions and Committees, Two Years

Howard W. Barlow, Director of the Washington State Institute of Technology at the State College of Washington, has been a member of ASEE since 1940. He served as a member of the General Council in 1947 and 1951.

Dr. Barlow received his B.S. from Purdue in 1927, his M.S. from the University of Minnesota in 1934, and his Eng. Sc.D. from NYU in 1941. He was a stress analyst and staff engineer for Glenn L. Martin Co. 1927–30, chief engineer for Gazley and LaSha National Aircraft Engineers in 1930 and president 1930–32. In 1932 he went to the University of Minnesota as instructor in aeronautical engineering and later went up to associate professor. He was visiting lecturer on aeronautics at New York University 1938–39, and in 1940 he went to Texas A. & M. as professor and head of aeronautical engineering. He was dean of engineering, director of the engineering experiment station and of the engineering extension service, and director of the college airport activity 1944–54. He became Director of the Washington State Institute of Technology in 1954.

For Treasurer, One Year

W. W. Burton, Employment Manager for Minnesota Mining and Manufacturing Company, has been a mem-

ber of ASEE since 1947. He is chairman of the Ethics Committee and past national chairman and a director of the Relations With Industry Division. His committee memberships include the Training Committee and Ethics Committee of ECPD. He is one of the founders of the Midwest College Placement Association. He is a member of the Board of Trustees of Breck School in Minneapolis.

Burton attended the University of Minnesota from 1930 to 1934, majoring in mathematics and business and has been staff lecturer in its Institute of Technology for several years.

CENSUS BUREAU AND AEC TO SURVEY INDUSTRIAL PARTICIPATION IN U.S. ATOMIC ENERGY PROGRAM

The Bureau of the Census, Department of Commerce, with the cooperation of the Atomic Energy Commission, sent out questionnaires during October to collect statistical information from private atomic energy manufacturers and processors to determine the extent of U. S. industrial participation in the program for the peaceful uses of atomic energy.

Figures are being collected so as to present year by year a comprehensive summary of the development, growth, and status of the atomic energy industry, private and public, including the number and value of shipments, the manufacture of atomic energy products, and the processing of raw materials and by-products. The Bureau of the Census will establish an annual series on the atomic energy industry as part of its regular program of statistics on manufacturing. The data collected in 1958 will be published as a report of the 1958 Census of Manufactures.

All firms manufacturing reactors, reactor components, fuel elements and other products in the atomic energy industry and processing radioisotopes and ores will be asked to contribute data. The Commission will send out the questionnaires to its contractor-operators of AEC installations, and will help to finance the initial collection of data from others by the Bureau of the Census.

The combined public and private statistics, covering 1957, will be issued by the Bureau of the Census as part of its regular services. Beginning with 1958 data, the survey will be reported annually by the Bureau.

NEW ADDRESS FOR NSF

The National Science Foundation has completed its move to new quarters. Its new address is 1951 Constitution Avenue, Washington 25, D. C. All NSF offices are now centralized in this one building. The telephone number is STerling 3-2140.

TEACHING POSITIONS AVAILABLE

AERONAUTICAL ENGINEERING: Applications are being received for two permanent positions in the Department of Aeronautical Engineering at the University of Alabama. Applicants for one position should have advanced degrees. The other opening could be filled by a person holding only a Bachelor's degree if he were to show promise of becoming a successful teacher. Opportunities for consulting and research are available; both are encouraged. A person who has earned a Ph.D. within recent years would sense an unusually attractive opportunity to develop a graduate program and teach in his chosen field. Salaries depend on qualifications—up to $9,000 for nine months for a professor. Usual academic tenure regulations apply; the university contributes toward retirement and insurance. Please address inquiries to: Colgan H. Bryan, Head, Department of Aeronautical Engineering, P. O. Box 1461, University, Alabama.

PROFESSORIAL APPOINTMENTS, each combining half teaching half research. Expanding activity has created positions for four Ph.D.'s with superior analytical and experimental ability. Among appropriate fields of interest are: electromagnetic theory and devices, electronics, dynamics and servosystems, aircraft structures, thermodynamics, hydrodynamics and fluid machinery, soil mechanics, physical metallurgy. Write D. C. Drucker, Chairman, Division of Engineering, Brown University, Providence 12, Rhode Island.

ASSISTANT OR ASSOCIATE PROFESsors of Aeronautical, Electrical, or Mechanical Engineering, Ph.D. required. Also, part-time teaching appointments for degree candidates. Apply to: Dean, School of Engineering, University of Southern California, Los Angeles 7, California.

DIRECTOR OF MEDICAL INSTRUmentation Laboratory. Must have majored in Electrical Engineering or Physics and must hold the Ph.D. degree. Must have had considerable experience in the field of Instrumentation and preferably some experience in Medical Instrumentation. Duties would consist of directing research of a small group of graduate students working in the area of new techniques in medical instrumentation and teaching one or two courses. Send inquiries with qualifications to F. B. Haynes, Head, Electrical Engineering Department, Drexel Institute of Technology, Philadelphia 4, Pa.

STAFF OPENINGS IN ELECTRICAL and Mechanical Engineering at Ph.D. and M.S. levels, salaries commensurate with qualifications. Apply, Dean, College of Engineering, Duke University, Durham, North Carolina.

DUE TO AN EXPANSION PROGRAM the Lain Technical Institute of Indianapolis, Indiana, is in need of instructors in Industrial Engineering Technology, Tool and Gauge Design, and Architectural Drafting. Previous teaching experience not necessary. Executive ability helpful. Write Lain Technical Institute, 601 North Delaware Street, Indianapolis 4, Indiana.

ELECTRICAL ENGINEERING PROfessors: Fast growing Engineering School on the West Coast needs three electronic-electrical engineers able to teach Circuits and Electronics, with a specialty in communications, industrial electronics or computers. M.S. degree plus industrial experience is the minimum requirement; a Ph.D. is desirable. Salary and rank will depend on experience. The department has just moved into a new building and needs aggressive men who wish to help develop curricula and laboratories. Apply: A. D. Graves, Dean of the College, Los Angeles State College, Los Angeles 32, California.

MECHANICAL ENGINEERING DEpartment needs additional staff for Thermodynamics, heat transfer, metallurgy and machine design, M.S., Ph.D. or equivalent required. Interest in research

desirable. Rank and salary dependent upon training and experience. Apply, Head, Mechanical Engineering Department, Louisiana State University, Baton Rouge, Louisiana.

PROFESSORS OR ASSOCIATES IN Civil, Electrical and Mechanical. Ph.D. required. Eleven months contracts. Resume to Dean Engineering, University of Santa Clara, Santa Clara, California.

ELECTRICAL ENGINEERING DEpartment faculty positions open for qualified persons in the fields of Network Theory, Electromagnetic Theory, Electronics and Control. Undergraduate and graduate teaching and research. Completion of doctorate required. Instructorships in Electrical Engineering for full time work with opportunities for graduate study, also available. Address, Department of Electrical Engineering, Rensselaer Polytechnic Institute, Troy, New York.

ASSOCIATE PROFESSOR OF ELECtrical Engineering—to teach and supervise research in Division of Engineering Research and Development effective September, 1959. Ten month basis. Ph.D. required or essentially completed. Write Head, Department of Electrical Engineering, University of Rhode Island, Kingston, Rhode Island.

CIVIL ENGINEERING STAFF POSItion in Sanitary and Hydraulic area. Open only to engineer with M.S. degree. Teaching and industrial experience desirable but not essential. Apply to W. W. Lorell, Head, Department of Civil Engineering, San Jose State College, San Jose, California.

POSITIONS AVAILABLE FOR QUALified physicist with Ph.D. and some teaching experience. For further details, write to the Department of Engineering Physics, University of Louisville, Louisville, Kentucky.

ELECTRICAL ENGINEERING DEpartment Head. Excellent opportunity available for young teacher with Ph.D. Should have teaching and industrial experience. College located in San Francisco Bay Area, electronics industry research, development and manufacturing center. Academic rank and salary open. Write to N. O. Gunderson, Head, Division of Engineering, San Jose State College, San Jose 14, California.

ASSISTANT, ASSOCIATE OR FULL Professor of Electrical Engineering, M.S. or Ph.D. required. Nine month salary range presently $5000–$9000. Full year appointments available. Salaries are increasing rapidly. Candidate should be well-prepared to teach in new undergraduate program with strong engineering science emphasis and in EE graduate (MS) program. Apply to A. T. Murphy; Head, Department of EE; University of Wichita; Wichita 14, Kansas.

TEACHING VACANCY, SEPTEMBER 1959: Young electrical engineer with at least Master's degree; appropriate salary and rank. Write Dean, Norwich University, Northfield, Vermont.

CHEMICAL ENG. TEACHING, REsearch Broad-gage Ph.D. needed for year-around position. Teaching: primarily graduate courses. Research: opportunity to do basic work in several fields, consult frequently on sponsored projects and develop own field of research. Unusual opportunity to build reputation. Attractive salary.
Apply: R. T. Ellington, Chairman, Educ. Prog., Institute Gas Technology, Chicago 16, Ill.

NEW MEMBERS OF ASEE

New Affiliate Members

October 21, 1958

North Idaho Junior College, 1000 West Garden Avenue, Coeur d'Alene, Idaho
D. H. Moser, Head of Engineering Department

Hillyer College, University of Hartford, Box 1948, Hartford 1, Conn.
Dr. Alans S. Wilson, President
Dr. Richard G. Clarke, Director of Research
Alexander H. Zerban, Dean of School of Engineering

Valparaiso Technical Institute, Valparaiso, Indiana
W. D. A. Peaslee, President
R. C. Patton, Dean

New Individual Members

October 22, 1958

ALVORD, HERBERT H., Associate Professor of Mechanical Engineering, University of Michigan, Ann Arbor, Mich. Keith W. Hall, Frederick K. Boutwell. M. E.; Mech. & Mat.

ASHWORTH, EDWIN R., Assistant Professor of Industrial Engineering and Management, Oklahoma State University, Stillwater, Okla. Earl J. Ferguson, H. G. Thuesen. I. E.; Engr. Econ.

BOGGS, JAMES H., Head, School of Mechanical Engineering, Oklahoma State University, Stillwater, Okla. Gerald E. Tanger, Wilson J. Bentley. M. E.; Aero. E.

BOULANGER, WESLEY P., Instructor in Civil Engineering, Montana State College, Bozeman, Mont. W. O. Keightley, E. R. Dodge. C. E.; Mech. & Mat.

BROTHERS, LEROY A., Dean, College of Engineering, Drexel Institute of Technology, Philadelphia 4, Pa. G. W. Zuspan, A. W. Grosvenor. Adm. Ed.

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50 new members this list
200 members previously added this fiscal year

250 new members this fiscal year

October 30, 1958

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50 new members this list
250 members previously added this fiscal year

300 new members this fiscal year

1959 ASEE–AEC SUMMER INSTITUTES

Six Summer Institutes on Nuclear Energy for engineering educators will be held this summer, sponsored by the Atomic Energy Commission and ASEE. Five of the Institutes are for teachers in engineering colleges with ECPD approved curricula. One is for teachers in technical institutes. Attendees are selected by subcommittees of the ASEE Nuclear Committee.

Applications for appointment may be obtained from the deans of engineering, directors of technical institutes, or from ASEE headquarters. They should be returned to Professor W. Leighton Collins, Secretary of the ASEE, University of Illinois, Urbana, Illinois by March 1, 1959.